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MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA.

THE COMPOSITION OF THE OIL-SEEDS OF INDIA.

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IN 1901 and again in 1903, details regarding the chemical composition of Indian food-grains and fodders, as determined in this laboratory, were published in the Agricultural Ledger (1901, No. 10, and, 1903, No. 7). These publications contain some information regarding the oil-seeds of India, but the number of specimens which had then been examined was too limited to admit of a definite opinion being formed regarding the variations which occur in the amount of oil in such seeds in different Provinces.

Since then a large number of specimens of oil-seeds received from various Provinces in India have been examined for oil, and their general composition in other particulars has also been determined. The details are set out in this Memoir.

There is indeed much less accurate information about oil-seeds than about the so-called food-grains. It is probable that all the large crushing firms in Europe and America possess a good knowledge of the amount of oil present in the seeds they deal with, but such information is not usually published. Standard books give but little information ; Church's "Food Grains" provides one analysis of one oil-seed, and other authors reproduce odd analyses. American writers are more liberal, but even their exhaustive literature does not, I believe, do justice to the subject. I have referred under the head of the individual seeds to such data as I

have been able to find. A correct knowledge of the amount of oil in these seeds is naturally of value to all parties concerned. To the agriculturist it is of importance to know whether the seed grown by him compares favourably or otherwise with what is grown elsewhere, and one of the chief points brought out by this series of analyses is the variation in the amount of oil which is found in the same seed grown in different Provinces. These differences are not always great, but in some this is the case. To the crusher too, such information must be of not less value, because the amount of oil expressible from any seed varies in a ratio even greater than is indicated by the percentage amount. When an oil-seed is crushed, it may be said that, when using the same mill and a like pressure, the cake will retain approximately the same amount of oil whatever the seed contains. For example, if two samples of an oil-seed, containing respectively 50 % and 40 % of oil, are crushed, and the cake contains 10 % of oil, the nett result is that the one will yield 50 minus $\frac{50 \times 10}{90} = 5{\cdot}5$ or $44{\cdot}5$ parts of oil, while the other will yield 40 minus $\frac{60 \times 10}{90} = 6{\cdot}7$ or $33{\cdot}3$ parts of oil.

Another important subject is touched upon in this Memoir, and about which more precise data will, it is hoped, be obtained in the future. After some of these analyses had been made, specimens of some oil-seeds which had been shown to be richer in oil in one Province than in another, were grown in the latter Province and the seed so obtained analysed. In most cases the result of the experiment indicated that the newly imported seed had suffered deterioration. Unfortunately, however, in all but one such experiment, the initial seed was not analysed, and this fact alone detracts much from the value of the experiments. For it will be obvious that, because certain specimen (say) of sessamum from the Deccan was found to be rich, it does not follow that a precisely equally good sample can be obtained a year or so later ; and if this latter is grown in another part of India and the seed analysed, and found to be less rich than the former sample, no proof is provided that depreciation has followed the transfer to the new Province. In one case, however,

the above indicated precautions were taken. Linseed was obtained from several parts of India and grown at Lyallpur in the Punjab. Some of this seed was analysed, as was also the newly-grown crop, and again in the second year the corresponding checks were made. I am permitted by the Director of Agriculture to refer to this experiment and, as the figures show, there seems to be distinctly less oil in the seed grown at Lyallpur than in the original. It is undesirable to draw general deductions from an isolated experiment, and we must hope that either imported oil-seeds into a Province possessing only poor qualities of the seed in question will become rapidly acclimatized and regain their former richness or that means may be found of increasing the amount of oil where the evidence indicates poverty in the seed.

The whole of the individual analyses have been incorporated in the text. These details render the pages a mass of statements, but I hope that those who are interested will find them more useful than if merely average figures had been given.

All the specimens could be readily classed under the genus to which they belong. But it was quite unsafe to try to differentiate between varieties, except in the case of some of the Brassicæ from Bengal, which Colonel Prain kindly identified for me in 1900. The specimens of Brassica varieties and of Sessamum included obviously seed of very different size and colour, and it was necessary to group them under corresponding heads. But the other oil-seeds are not so readily divided, and these have, therefore, been merely grouped according to the Province of origin.

Regarding the analytical methods adopted, reference need only be made to that employed for the determination of the oil. When oil-seeds are crushed, they usually assume a very pasty consistence, and it is impossible to ensure the direct disintegration of all the oil-bearing cells. I have, therefore, adopted the plan of first extracting most of the oil from the weighed portion, and then air-drying, re-crushing and re-extracting the residue. After removal of most of the oil, the material is very readily disintegrated in an iron mortar. The procedure is as follows :—The weighed oil-seed, as crushed in a mill (Castor bean was crushed in a mortar), was

extracted with ether in a soxhlet for about two hours ; the paper case was taken out and exposed until the ether had vaporized ; the oil-flask removed, dried, and weighed as usual. The air-dry and partially exhausted material was then pounded in an iron mortar which was itself placed on a large sheet of clean paper, the object of the latter being to secure any material which might be thrown out of the mortar during the disintegration. Although this precaution was naturally necessary, the experience was that very little material was ejected during the operation. After this pulverization, the material was carefully transferred to the paper case again, and extracted for a further period of 1 hour to $1\frac{1}{2}$ hours. The amount of oil obtained by this second extraction was usually considerable, varying from ·020 grm. to ·150 grm. It may seem at first sight a dangerous process to take weighed material and grind it in a mortar in this manner and that the risk of loss must be great. Apart from it being the only method I could adopt for the purpose, the risk of serious error is not really great. The weight of material employed was about 3 grms. and, supposing that so much as $\frac{1}{10}$ part of this were lost through carelessness (no such loss need ever occur), it would mean a loss of oil not greater than ·015 grms., and this is equal to ·5 per cent. as reckoned on the fresh material. Had this second crushing been neglected, the loss, due to unextracted oil, would often have amounted to ·1 grm. or about 3·33 per cent.

The list of seeds which have been examined includes :—

Arachis hypogæa (Earthnut).
Bassia latifolia (Mowha).
Brassica (Sarson, Toria, Rai).
Carthamus tinctorius (Safflower).
Eruca sativa (Taramira).
Gossypium (Cotton seed).
Guizotia abyssynica (Niger).
Linum usitatissimum (Linseed).
Papaver somniferum (Poppy).
Ricinus communis (Castor bean).
Sessamum indicum (Til, jinjilly).

ARACHIS HYPOGÆA—(*Earthnut*).

	Bombay and Madras only.
Area in acres	500,000
Outturn in tons	200,000

Some information regarding this crop was published in Bulletins Nos. 28 and 41 of the Madras Agricultural Department, in the latter of which it was shown that the "Mauritius" variety contained generally 44 to 49 per cent. of oil, whereas the "indigenous" kernels contained only 40 to 44 per cent. Since then a number of other samples have been examined not only from Madras but also from the Bombay Presidency and from Burma, and these are detailed in the subjoined statements. Most of these newer samples have, however, been recently imported, and although of interest as showing the quality of the newer seed, they do not refer to such extensive areas as the "indigenous" or "deshi" samples. Generally speaking, what was observed among the former Madras specimens, holds also for those from the Bombay Presidency, namely, the "indigenous" seed is not so rich in oil as the newly imported. The Burmese specimens are, however, as rich as the latter. The table shows that the "indigenous" seed contains from 40 to 45 per cent., whilst the imported varieties contain from 45 to 50 per cent.; a difference almost exactly similar to that previously observed in Madras specimens. These figures refer to the proportion of oil in kernels. The amount present in the whole seed, including the shell, has been calculated on the assumption that the shell contains no oil, and these figures are also entered in the statement.

Sample No.	Vernacular name.	District.	Kernels. Per cent.	Shells. Per cent.	Oil in kernels. Per cent.	Oil in whole seed. Per cent.	Weight of 100 kernels. Grms.
		Madras Presidency.					
714—04	Groundnut ...	North Arcot...	74·08	25·92	45·27	33·54	30·4
715—04	Country ...	Do. ...	72·95	27·05	43·19	31·51	26·9
716—04	Groundnut ...	Do. ...	80·04	19·96	45·95	36·78	39·2
717—04	Mauritius ...	Do. ...	77·94	22·06	48·12	37·50	44·5
1042—04	Do. ...	Do. ...	78·18	21·92	48·51	37·93	39·1
1198—04	"London" ...	South Arcot ...	75·40	24·60	49·36	37·22	56·1
811—04	Groundnut ...	Tanjore ...	80·16	19·84	49·16	39·41	38·7
1—06	Small Japanese ...	Palur ...	81·18	18·82	48·34	39·24	...
2—06	Big Japanese	Do. ...	77·22	22·78	48·33	37·32	...

Sample No.	Vernacular name.	District.	Kernels, Per cent.	Shells. Per cent.	Oil in kernels. Per cent.	Oil in whole seed. Per cent.	Weight of 100 kernels. Grms.
		Madras Presidency—(concld.)					
3—06	Tata selected	Palur ...	76·25	23·75	48·56	37·03	...
4—06	Pondicherry	Do. ...	78·71	21·29	48·75	38·37	.
5—06	Virginia ...	Do. ...	75·24	24·76	48·05	36·15	...
6—06	Spanish Peanut ...	Do. ...	78·07	21·93	46·72	36·47	...
7—06	Barbados ...	Do. ...	70·96	29·04	46·14	32·74	...
8—06	Mauritius, Ceylon ...	Do. ...	76·90	23·10	49·32	37·93	...
9—06	Tanjore ...	Do. ...	80·58	19·42	49·37	39·78	..
10—06	Madagascar...	Do. ...	75·40	24·60	48·28	36·40	...
11—06	Local Mauritius ...	Do. ...	79·55	20·45	49·21	39·15	...
12—06	Native ...	Do. ...	73·94	26·06	44·88	33·18	...
13—04	Barbados, Ceylon ...	Do. ...	77·55	22·45	44·90	34·82	...
14—06	Mauritius do.	Do. ...	78·22	21·78	47·78	37·37	...
15—06	Mauritius from Mauritius ...	Do. ...	76·66	23·34	48·65	37·30	...

Average of 1900 samples :—

	Kernels. Per cent.	Shells. Per cent.	Oil in kernels. Per cent.
8 Specimens of "indigenous" seed	74·8	25·2	41·82
10 Do. "Mauritius" seed	76·8	23·2	46·09

Sample No.	Vernacular Name.	District.	Kernels. Per cent.	Shells. Per cent.	Oil in kernels. Per cent.	Oil in whole seed. Per cent.	Weight of 100 kernels. Grms.
		Bombay Presidency.					
68—06	Japan, big ...	Sind ...	...	...	48·70	...	...
69—06	Do. small...	Do. ...	...	...	49·51	...	...
70—06	Java ...	Do. ...	...	...	44·74	...	...
71—06	Mozambique	Do. ...	...	...	49·76	...	...
72—06	Pondicherry	Do. ...	...	...	49·23	...	..
73—06	Senegal ...	Do. ...	...	...	48·46	...	...
74—06	Spanish Peanut ...	Do. ...	...	...	48·08	...	...
75—06	Surti, Deshi (country) ...	Do. ...	...	...	41·62	...	...
76—06	Virginia ...	Do. ...	...	...	47·10	...	...
463—04	Japanese, big	Surat ...	75·9	24·1	45·65	34·74	75·0
464—04	Do. small	Do. ...	80·89	19·11	49·75	40·24	52·0
465—04	Pondicherry	Do. ...	72·48	27·52	43·27	31·37	39·0
466—04	Spanish ...	Do. ...	79·22	20·78	48·87	38·72	46·0
467—04	Virginia ..	Do. .	76·85	23·15	47·33	36·37	68·0
468—04	Deshi, country	Do. ...	72·41	27·59	45·27	32·78	41·0
214—06	Virginia ...	Do. ...	...	...	47·21	...	...
215—06	Pondicherry	Do. ...	...	...	48·31	...	...
216—06	Japanese, big	Do. ...	...	...	47·68	..	...
217—06	Do. small	Do. ...	...	...	50·40	...	...
218—06	Spanish Peanut ...	Do. ...	...	...	51·43	...	...

Sample No.	Vernacular name.	District.	Kernels. Per cent.	Shells. Per cent.	Oil in kernels. Per cent.	Oil in whole seed. Per cent.	Weight of 100 kernels. Grms.
		Bombay Presidency—(concld.)					
219—06	Local ...	Surat ...	..	...	47·43	...	...
1177—04	Groundnut ...	Belgaum ..	...		41·49	..	27·8
1181—04	Do. ..	Do. ...	77·32	22·68	42·96	33·22	30·9
1185—04	Do. ...	Do. ...	...	...	42·52	..	31·0
251—04	Do. ...	Poona ...	76·44	23·56	43·32	...	33·6
254—04	Do. ...	Ahmednagar...	...	...	44·86	...	41·3
262—04	Do. ...	Sholapur ..	...	...	40·57	...	24·4
325—04	Do. ...	Satara ...	...	...	45·65	...	38·6
		Burma.					
55—04	Groundnut ...	Meiktila ...	75·19	24·81	46·14	34·69	49·4
655—04	Do. ...	Prome ...	78·45	21·55	50·21	39·39	43·2
747—04	Mayaype ...	Minbu ...	72·74	27·26	48·58	35·34	36·7
1271—04	Groundnut ...	Hasmongkham	67·77	32·23	44·26	30·00	33·9
1288—04	Myipi ...	Central Burmah.	74·78	25·22	46·36	34·67	38·3
1294—04	Do. ...	Kengtung ...	65·34	34·66	46·06	30·10	34·5

Average composition (*Kernels only*) :—

	Bombay.	Burma.	Madras.
Moisture	6·83	7·26	6·28
Oil	45·36	47·26	46·34
Albuminoids	26·20	26·09	25·59
Soluble Carbohydrates	16·80	14·72	17·42
Woody fibre	2·09	2·05	1·95
Soluble mineral matter	2·63	2·57	2·37
Sand	·09	·05	·05
	100·00	100·00	100·00
Total Nitrogen	4·33	4·24	4·32
Albuminoid Nitrogen	4·19	4·17	4·09

Average proportion of shells and kernels :—

	Bombay.	Burma.	Madras.
Kernels, per cent	76·44	72·38	76·14
Shells, per cent	23·56	27·62	23·86

Composition of whole seed calculated on the assumption that the shells are entirely indigestible "woody fibre."

	Bombay.	Burma.	Madras.
Moisture	5·23	5·26	4·78
Oil	34·61	34·20	35·28
Albuminoids	20·05	18·90	19·50
Soluble Carbohydrates	12·87	10·63	13·25
Woody fibre	25·16	29·11	25·34
Soluble mineral matter	2·01	1·86	1·81
Sand	·07	·04	·04
	100·00	100·00	100·00
Total Nitrogen	3·32	3·07	3·29
Albuminoid Nitrogen	3·20	3·02	3·12

BASSIA LATIFOLIA—*Mowha seed (Kernels).*

The number of specimens of this seed which has been examined is too small to admit of any general deductions. The analyses are inserted, however, because of the very limited information on the subject which is available.

Sample No.	Local Name.	District.	Oil. Per cent.
	Central Provinces.		
124—04	......	Nimar	48·13
181—04	Gulli	Seoni	36·01
	United Provinces.		
1070—04	Mahua	Sultanpur	48·15
1071—04	Do.	Do.	46·95
1072—04	Do.	Do.	47·11
1073—04	Do.	Do.	48·67
1074—04	Do.	Do.	49·04
1075—04	Do.	Do.	46·60
1076—04	Do.	Do.	49·19
1077—04	Do.	Do.	49·19

BRASSICA.

	Area in British India.	Average yield.
	Acres.	Tons.
Grown as single crop ...	3,500,000	850,000
Grown as mixed crop ...	2,500,000	

There are few crops in India which include such a variety of seed as the Brassicæ. The individual crops appear to be largely mixtures, and it would have been an advantage if specimens of the pure varieties could have been examined in addition to the specimens of local production, but no opportunity occurred for this. However, since some of the most representative samples, as obtained from different districts, were similar to one another, it was possible to classify them in a great measure. The specimens fall under the following chief groups: "Yellow sarson" (probably Brassica campestris), twenty-five specimens chiefly from the United Provinces; and red or slaty coloured seed of various shapes and sizes, sixty-two specimens. The latter have been sub-divided according to colour and size into Sarshaf or Toria from the Punjab, a slaty brown or dark red seed weighing

from[1] ·2 to ·4 grm. per 100 seeds, and "Sarson kali" from the United Provinces similar in size to "Sarshaf," but redder coloured ; and secondly, the "Rai" of the Punjab, a much smaller seed than the foregoing, weighing from ·07 to ·15 grm. per 100 seeds. The other samples have been brought into this classification as far as possible, though characterized by difference in shape, colour and weight.

Yellow Sarson —The fifteen specimens from the United Provinces were uniform in colour and comparatively so in other respects. Their weight varied from ·41 to ·71 grm. per 100 seeds, and if one or two extremes are excluded, the variation is from about ·48 to ·68 grm. It is the heaviest of the varieties of Brassica. The amount of oil varied from 44 to 49 per cent. The Assam specimens were distinctly smaller, weighed ·3 to ·4 grm. per 100. and contained apparently less oil. The specimens from other Provinces were too few in number to admit of general deductions, but they do not appear to contain so much oil as the United Provinces specimens.

"*Sarshaf*" and "*Toria*" from the Punjab are seeds which are characterized by some irregularity in colour and shape. Whether the crop throughout the Province is a mixture, or whether these characteristics are common to the variety, is uncertain. Otherwise the seed is fairly uniform. The weight varies from ·21 to ·41, or excluding extremes ·25 to ·35. It contains generally from 37 to 45 per cent. of oil, *i.e.*, very appreciably less than the yellow seed. Specimens of "Kali Sarson" from the United Provinces were somewhat larger, and distinctly redder in colour. These twelve specimens weighed from ·3 to ·5 and contained from 39 to 46 per cent. of oil, *i.e.*, much about the same as Punjab Sarshaf. From Partabgarh, however, two specimens of a much larger seed were received ; they weighed ·66 grm. and contained 46 per cent. of oil. The remaining twenty-five specimens which I have classed under this group varied much more in weight, colour and percentage of oil ; some of them

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[1] In order to abbreviate this expression of the weight of seeds the mere figures are frequently used in the text by themselves, such as "weight of seeds ·2 to ·4" would mean ·2 to ·4 grm. per 100 seeds.

contained only 33 per cent. oil. The "Toria" from Sind was similar in appearance to that of the Punjab.

Thirdly, the samples of the Punjab "Rai," with two of "Desi-rai" from the United Provinces, have been classed together, because they are distinctly smaller than the foregoing, red in colour and contained less oil; their weight varied from ·07 to ·15, and the percentage of oil varied from 27 to 37.

Among the few references by foreign writers to the amount of oil in Brassica, Armsby mentions 55 per cent. as the highest, 36 per cent. as the lowest and 42·5 per cent. as the mean of a number of specimens.

YELLOW SARSON.

Sample No.	Local Name.	District.	Oil. Per cent.	Weight of 100 seeds. Grms.
		United Provinces.		
664—04	Sarson—Zard	Cawnpore	48·64	·483
665—04	Do.	Do.	47·91	·495
935—04	Do.	Do.	45·47	·603
943—04	Do.	Do.	45·73	·603
939—04	Do.	Unao	48·52	·504
945—04	Do.	Do.	48·16	·522
937—04	Do.	Partabgarh	49·23	·413
940—04	Do.	Do.	48·75	·604
941—04	Do.	Do.	46·33	·640
944—04	Do.	Do.	48·92	·404
936—04	Do.	Do.	46·04	·632
942—04	Do.	Do.	43·84	·640
946—04	Do.	Do	44·60	·630
923—04	Do.	Meerut	45·67	·673
938—04	Do.	Do.	45·41	·710
		Assam.		
405—04	"White" Mustard	Sylhet	45·10	·368
703—04	"Yellow" Mustard	Kamrup	42·61	·315
704—04	Do.	Do.	36·88	·338
238—04	Obhota Sariah	Jorhat	43·68	·399
237—04	Baga do.	Do.	42·68	·326
		Bombay Presidency.		
401—04	Rape	Nadiad	35·72	·439
454—04	Sarson	Surat	43·00	·531
		Central Provinces.		
158—04	Sarson	Raipur	46·75	·466
918—04	Rapeseed—"Yellow" ...	Bilaspur	47·21	·296
		Punjab.		
86—04	Sarshaf	Kangra	43·88	·489

SARSON—(*other sorts*).

Sample No.	Local Name.	District.	Oil. Per cent.	Weight of 100 seeds. Grms.	
		Punjab.			
89—04	Sarshaf	Muzaffargarh	45·49	·293	Slaty brown and dark red seed.
19—04	Toria	Chenab Canal	44·94	·327	
85—06	Sarshaf	Kangra	44·33	·250	
96—04	Do.	Ambala	42·45	·297	
14—04	Do	Gurgaon	41·95	·415	
68—04	Toria	Montgomery	41·37	·268	
20—04	Sarshaf	Chenab Canal	40·66	·339	
143—04	Toria	Gujrat	40·33	·288	
138—04	Sarshaf	Sialkot	40·04	·212	
137—04	Toria	Do.	39·46	·236	
144—04	Sarshaf	Gujrat	39·45	·349	
152—04	Do.	Rawalpindi	38·53	·273	
95—04	Toria	Ambala	37·96	·292	
9—04	Sarshaf	Hissar	37·88	·344	
88—04	Toria	Muzaffargarh	36·89	·287	
		United Provinces.			
666—04	Sarson—Kali	Cawnpore	39·86	·271	Seed similar in size to Punjab Sarshaf, but redder in colour.
667—04	Do.	Do.	39·03	·309	
950—04	Do.	Do.	39·05	·349	
951—04	Do.	Do.	39·35	·314	
924—04	Do.	Unao	40·64	·366	
949—04	Do.	Do.	40·44	·383	
948—04	Do.	Aligarh	46·73	·478	
952—04	Do.	Do.	46·37	·528	
947—04	Do.	Meerut	40·70	·398	
953—04	Do.	Do.	40·34	·413	
954—04	Do.	Aligarh	41·07	·359	
957—04	Do.	Do.	40·94	·362	
955—04	Sarson—Red	Partabgarh	46·16	·665	
956—04	Do.	Do.	45·53	·660	
958—04	Rai—Siah	Do.	41·80	·368	
959—04	Do.	Do.	41·32	·315	
		Central Provinces.			
197—04	Mustard	Balaghat	46·09	·292	Large, dark red, round seed.
105—04	Sarson	Jabalpur	45·61	·304	
159—04	Rai	Raipur	44·24	·295	
170—04	Mustard	Sambalpur	43·43	·340	
106—04	Rai	Jabalpur	42·16	·213	Irregularly shaped dark red seed.
292—04	Do.	Mandla	40·16	·231	
116—04	Mustard	Hoshangabad	36·34	·276	
133—04	Do.	Damoh	36·16	·229	
219—04	Do.	Chanda	34·36	·241	
220—04	Do.	Do.	32·45	·208	
209—04	Do.	Narsingpur	38·22	·156	Dark red small round seed.
126—04	Do.	Nimar	34·96	·153	
77—04	Rai	Seoni	33·08	·142	
132—04	Jagni or Sarson	Damoh	40·57	·272	
917—04	Rapeseed—"Red"	Bilaspur	45·62	·313	
		Assam.			
239—04	Ranga Sariah	Jorhat	41·11	·327	
240—04	Kala do.	Do.	35·93	·364	
407—04	Mustard	Sylhet	41·50	·286	
705—04	Black Mustard	Kamrup	35·65	·280	
		Bombay Presidency.			
901—04	Toria	Jamrao Canal, Sind	39·23	·298	
902—04	Do.	Do. do.	41·55	·345	

SARSON—(*other sorts*)—contd.

Sample No.	Local Name.	District.	Oil. Per cent.	Weight of 100 seeds. Grms.	
		Bengal.			
475—04	Mustard	... ...	46·60	·300	
		Burmah.			
565—04	Monyin	Prome ...	45·59	·314	
		RAI.			
		Punjab.			
156—04	Rai	Rawalpindi	37·48	·152	Colour similar to Sarshaf, but seed smaller.
147—04	Do.	Gujrat	36·78	·122	
92—04	Do.	Muzaffargarh	35·82	·156	
99—04	Do.	Ambala	31·27	·158	
84—04	Do.	Kangra	35·28	·090	
17—04	Do.	Gurgaon	34·13	·113	
12—04	Do. ...	Hissar	29·79	·090	
23—04	Do.	Chenab Canal	29·73	·084	
71—04	Do.	Montgomery	28·61	·077	
141—04	Do.	Sialkot	27·21	·081	
		United Provinces.			
925—04	Desi-Rai ...	Aligarh ...	36·05	·176	
960—04	Do. ...	Do. ...	35·62	·168	

Bengal.

(Published in Agricultural Ledger, 1903, No. 7, pp. 160-1.)

BRASSICA JUNCEA, H. f. & T.

Syn.: Sinapis juncea. Sinapis ramosa, Roxb.

English: Indian Mustard.

Vern.: Asl-rai.

Sample No.	Local Name.	District.	Oil. Per cent.
380—00	"Kajli Sarsa"	24-Parganas	40·22
385—00	Lalki tori	Dumraon	39·46
518—00	Rai	Nadia	32·51
520—00	Do.	Arraria	40·84
	BRASSICA NAPUS, Linn.; var. Dichotoma. English: Indian Rape. Vern.: Tori, Lutni, Moghi.		
388—00	Latni	Hazaribagh	38·21
496—00	Lotni	Ranchi	40·00
519—00	Jehanabad	Bengal	40·18
	BRASSICA CAMPESTRIS, Linn.; var. Sarson, Prain. English: Indian Colza. Vern.: Sarson, Sweti.		
383—00	Piarka tori	Dumraon	41·51
384—00	Lalka tora	Do.	39·73
386—00	Piarki tori	Do.	41·42
389—00	Seta Sarisa	Rangpur	42·62
521—00	... ...	Arrah	43·92

The following illustrates the average composition of the seed :—

	Sarshaf or Toria, *Punjab.*	Rai, *Punjab.*	Rai, *Central Provinces.*	Yellow Sarson, *Central Provinces.*	Yellow Sarson, *United Provinces.*	Yellow Sarson, *Assam.*	Sarson, other sorts, *United Provinces.*
Moisture ...	6·98	7·06	6·04	5·46	6·12	7·01	5·96
Oil ...	39·76	30·28	38·63	45·34	47·42	41·59	40·45
Albuminoids ..	17·26	19·88	18·99	15·96	17·29	18·54	18·10
Soluble Carbohydrates	25·63	30·69	27·64	24·06	21·88	23·51	26·55
Woody fibre	5·37	5·92	4·90	4·39	3·59	3·84	4·74
Soluble mineral matter...	4·11	4·99	3·01	3·75	3·50	4·21	3·86
Sand ...	·89	1·18	·79	1·04	·19	1·30	·34
	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Total Nitrogen ...	3·25	3·74	3·74	3·54	2·97	3·23	3·39
Albuminoid Nitrogen ...	2·76	3·18	3·04	2·55	2·77	2·97	2·89

(Published in Agricultural Ledger, 1903, No. 7, pp. 160-1.)

Bengal.

	Brassica juncea. 4 samples, average.	Brassica napus. 3 samples, average.	Brassica campestris. 5 samples, average.
Moisture	7·68	6·69	7·21
Oil	38·26	39·46	41·82
Albuminoids...	19·14	18·29	20·09
Soluble Carbohydrates... ...	24·10	23·18	22·04
Woody fibre	5·48	5·24	4·47
Soluble mineral matter	4·29	4·49	3·96
Sand and Silica	1·06	2·84	·39
	100·00	100·00	100·00
Total Nitrogen	3·31	3·17	3·47
Albuminoid Nitrogen	3·06	2·93	3·21

CARTHAMUS TINCTORIUS—(*Safflower seed*).

The accompanying statement exhibits the proportion of oil in thirty samples of *Safflower* seed.

The variation in the amount of oil is not great. The one sample from Bengal contains only 22·47 per cent., but it seemed to be discoloured somewhat; and one sample from Bellary and one from Chhindwara contained less than 24 per cent. But the remainder contained from 26 up to about 32 per cent. The Central Provinces samples contained a little earth, but all the others were clean. Any such earth was of course excluded from the portions analysed.

Sample No.	District.	Oil. Per cent.	Weight of 100 seeds. Grms.
	Central Provinces.		
79—04	Seoni	30·49	6·774
163—04	Raipur	26·57	3·405
403—04	Balaghat	26·42	5·264
578—04	Chhindwara	23·54	5·953
707—04	Betul	31·82	6·311
914—04	Bilaspur	29·93	4·379
	Bombay Presidency.		
241—04	Nasik	31·23	4·963
248—04	Poona	30·03	4·910
252—04	Ahmednagar	31·02	4·440
261—04	Sholapur	29·56	4·931
272—04	Dharwar	30·16	4·986
324—04	Satara	32·23	5·218
400—04	Nadiad	28·79	4·210
455—04	Surat	29·51	5·516
471—06	Poona	31·27	5·028
	Madras Presidency.		
404—04	Anantapur	31·05	3·890
500—04	Gooty	33·55	4·153
567—04	Nandyal	30·63	3·885
814—04	Kurnool	29·96	4·622
815—04	Kurnool	30·64	4·540
1034—04	Gooty	28·69	3·916
1047—04	Bellary	26·60	2·973
1052—04	Do.	23·88	4·559
	United Provinces.		
672—04	Cawnpore	28·11	3·348
673—04	Do.	29·00	3·670
927—04	Do.	27·94	4·600
968—04	Partabgarh...	29·49	4·204
969—04	Cawnpore	28·40	4·936
970—04	Partabgarh...	29·78	4·269
	Bengal.		
477—04	....	22·47	3·209

AVERAGE COMPOSITION.

	Central Provinces.	Bombay Presidency.	Madras Presidency.	United Provinces.
Moisture	5·31	5·22	6·22	6·16
Oil	27·13	29·85	29·83	27·45
Albuminoids	9·38	12·06	12·66	11·50
Soluble Carbohydrates	27·36	24·91	23·75	25·14
Woody fibre	27·43	25·94	24·46	27·42
Soluble mineral matter	2·48	1·97	2·48	2·23
Sand	·91	·05	·60	·10
	100·00	100·00	100·00	100·00
Total Nitrogen	1·64	2·37	2·16	2·07
Albuminoid Nitrogen	1·56	1·93	2·07	1·84

ERUCA SATIVA.—(*Vern. : Taramira.*)

Some specimens of this were received from the Punjab and the United Provinces, together with one sample from Bengal. As will be seen from an inspection of the figures, the specimens from the United Provinces contain appreciably more oil than those from the Punjab, and since this difference is regular, it may be presumed to be a general one. One cannot of course make deductions from the one Bengal specimen. The samples were fairly free from earthy materials.

Sample No.	Local Name.	District.	Oil. Per cent.	Weight of 100 seeds. Grms.
		Punjab.		
11—04	Taramira	Hissar	31·96	·274
16—04	Ditto	Gurgaon	34·77	·321
22—04	Ditto	Chenab Canal	25·40	·248
70—04	Ditto	Montgomery	27·33	·227
91—04	Ditto	Muzaffergarh	30·06	·285
98—04	Ditto	Ambala	32·82	·408
140—04	Ditto	Sialkot	28·12	·206
146—04	Ditto	Gujrat	32·57	·326
154—04	Ditto	Rawalpindi	30·24	·169
		Bengal.		
588—04	Taramira	......	33·05	·264
		United Provinces.		
926—04	Duan or Taramira ...	Partabgarh	31·72	·345
961—04	Ditto ...	Cawnpore	36·32	·393
962—04	Ditto ...	Partabgarh	31·30	·336
963—04	Ditto ..	Aligarh	36·71	·434
668—04	Ditto ...	Cawnpore	33·65	·258
669—04	Ditto ...	Do.	31·39	·251
964—04	Ditto ...	Meerut	33·69	·448
965—04	Ditto ...	Do.	34·40	·507
966—04	Ditto ...	Aligarh	36·57	·411
967—04	Ditto ...	Cawnpore	36·16	·442

AVERAGE COMPOSITION.

	Punjab.	United Provinces.
Moisture	6·81	6·69
Oil	28·99	33·33
Albuminoids	22·82	21·56
Soluble Carbohydrates	29·51	28·63
Woody fibre	5·41	5·19
Soluble mineral matter	4·62	3·92
Sand	1·84	·68
	100·00	100·00
Total Nitrogen	4·21	4·19
Albuminoid Nitrogen	3·65	3·45

GOSSYPIUM—(*Cotton-seed*).

Average area in acres ...	20,000,000
Approximate outturn in tons ...	1,200,000

Detailed information regarding the amount of oil in Indian cotton-seed was published in Agricultural Ledger No. 9 of 1903, and a summary only is inserted here.

	Oil in whole seed. Per cent.
26 specimens from Madras Presidency ...	17·41
18 " Bombay " ...	17·66
15 " Central Provinces ...	19·65
15 " United " ...	19·89

The variation in individual samples was only small, being from 15 to 21 in extreme cases. The amount of oil contained in Indian seed is then very much less than in American, which contains upwards of 30 per cent. The Indian seed is also smaller. Specimens of American weighed 12 to 18 grammes per 100 seeds, and Egyptian 10 to 11 grammes, whilst Indian seed weighed only 5 to 7 grammes.

GUIZOTIA ABYSSYNICA—(*Niger*).

The specimens of this seed were characterized by very considerable uniformity in colour, size of seed and amount of oil.

Sample No.	Local Name.	District.	Oil. Per cent.	Weight of 100 seeds. Grms.
		Central Provinces.		
62—04	Ramtilli ...	Sagor ...	38·85	·303
78—04	Jagni ...	Seoni ...	39·06	·288
104—04	Ramtilli ...	Jabalpur ...	38·78	·268
122—04	Do. ...	Nimar ...	41·71	·298
131—04	Do. or Jagni ...	Damoh ...	39·03	·341
200—04	Do. or Sarsoa ...	Balaghat ...	37·30	·204
207—04	Jagni or Ramtilla ...	Narsingpur ...	36·17	·244
294—04	Do. ...	Mandla ...	36·75	·274
575—04	Jagni ...	Chhindwara ...	36·94	·269
710—04	Do. ...	Betul ...	38·57	·215
919—04	Ramtilla ...	Bilaspur ...	39·96	·360
		Bombay Presidency.		
244—04	Niger ...	Nasik ...	39·90	·334
250—04	Do. ...	Poona ...	38·28	·373
255—04	Do. ...	Ahmednagar ...	41·40	·328
260—04	Do. ...	Sholapur ...	42·00	·409
263—04	Do. ...	Kolaba ...	39·29	·325
270—04	Do. ...	Dharwar ...	40·83	·418
327—04	Do. ...	Satara ...	40·56	·350
413—04	Do. ...	Thana ...	41·77	·410
456—04	Kharsani ...	Surat ...	39·29	·417
473—04	Niger ...	Poona ...	43·27	·416

Sample No.	Local Name.	District.	Oil. Per cent.	Weight of 100 seeds. Grms.
		Madras Presidency.		
448—04	Niger	Salem	41·47	·422
533—04	Do.	Berhampur	37·88	·337
740—04	Valesellu	Ganjam	37·47	·311
810—04	Niger	Do.	40·40	·366
1036—04	Do.	Salem	39·45	·394
1046—04	Gronuvulu ...	Bellary	41·87	·464
1051—04	Do.	Do.	41·89	·463
1063—04	Niger	Hasur, Salem	36·37	·370
1062—04	Do.	Do. Do.	36·29	·348
		Bengal.		
494—04	Niger	... ...	40·33	·378

AVERAGE COMPOSITION.

	Central Provinces.	Bombay Presidency.	Madras Presidency.
Moisture	5·53	5·33	6·03
Oil	38·53	39·95	39·10
Albuminoids	18·54	19·02	17·94
Soluble Carbohydrates	19·08	17·99	19·32
Woody fibre	12·31	12·54	11·94
Soluble mineral matter	5·29	4·64	5·18
Sand	·72	·53	·49
	100·00	100·00	100·00
Total Nitrogen	3·07	3·26	3·02
Albuminoid Nitrogen	2·97	3·04	2·87

LINUM USITATISSIMUM—(*Linseed*).

	Area in British India. Acres.	Yield. Tons.
Grown as single crop	3,000,000	300,000
Grown as mixed crop	500,000	

The accompanying statement exhibits the percentage of oil in fifty-four samples of *Linseed* which have been received from the several Provinces named. There is, on the whole, remarkably little variation in the proportion of oil. The Central Provinces and the United Provinces samples contain up to 44 per cent., and some of the Punjab samples fall as low as 37 per cent. (one as low as 35·6) but these are the extremes.

Most of them were brown linseed. One sample from Nimar and one from Cawnpore were practically wholly white ; and samples from Surat, Wardha, Hoshangabad, Narsingpur and Sambalpur contained more or less white linseed. All these contained high

proportions of oil, but at the same time equally high proportions were contained by pure brown linseed, so that there is no evidence to show that the one contains generally more oil than the other.

Some of the seed was distinctly small, such as that from Kangra and Rawalpindi, but there is not much evidence that any connection exists between the size of the seed and the amount of oil. Some of the larger Central Provinces varieties weighing ·8 or ·9 gramme per 100 seeds contain only as much oil as No. 920—04 from Bilaspur which weighed only ·55 gramme. At the same time it may be said that all the samples of bold seeds, weighing ·7 gramme or more per 100, contain high percentages of oil.

The only samples which were not clean were those from the Punjab. These, excepting that from the Kangra district, were mixtures of large and small linseed together with rape, wheat, etc., and straw, and they compared very badly with the general purity of the samples from other parts of India.

Sample No.	District.	Colour.	Oil. Per cent.	Weight of 100 seeds. Grms.
		Punjab.		
10—04	Hissar ...	Brown	40·40	·452
15—04	Gurgaon ...	Do.	41·50	·560
21—04	Chenab Canal ...	Do.	41·91	·609
69—04	Montgomery ...	Do.	37·91	·459
83—04	Kangra ...	Do.	38·61	·286
90—04	Muzaffargarh ...	Do.	35·60	·581
97—04	Ambala ...	Do.	37·59	·553
139—04	Sialkot ...	Do.	38·02	·614
145—04	Gujrat ...	Do.	39·41	·630
153—04	Rawalpindi ...	Do.	37·14	·395
		Central Provinces.		
63—04	Saugor ...	Brown	42·43	·967
76—04	Seoni ...	Do.	43·35	·710
103—04	Jabalpur ...	Do.	42·93	·721
115—04	Hoshangabad ...	¼ White	40·64	1·029
123—04	Nimar ...	White	43·64	·757
128—04	Damoh ...	Brown	44·20	·890
160—04	Raipur ...	Do.	39·89	·520
176—04	Sambalpur ...	¼ White	42·09	·724
194—04	Balaghat ...	Brown	42·90	·544
206—04	Narsingpur ...	½ White	42·77	·854
221—04	Chanda ...	Brown	40·74	·815
222—04	Do. ...	Do.	41·88	·752
223—04	Do. ...	Do.	43·15	·788
293—04	Mandla ...	Do.	40·17	·523
542—04	Hoshangabad ...	"Khakhri" ½ white...	43·93	·934
543—04	Do. ...	"Lal," brown ...	42·81	·861
848—04	Wardha ...	White	43·80	·800
549—04	Do. ...	"Red," brown ...	36·47	·818

Sample No.	District.	Colour.	Oil. Per cent.	Weight of 100 seeds. Grms.
		Central Provinces—(concld.)		
572—04	Chhindwara ...	"Red," brown	43·02	,831
711—04	Betul	Brown	41·73	.773
920—04	Bilaspur ...	,, ...	42·05	·552
		Bombay Presidency.		
245—04	Nasik	Brown	43·63	·872
246—04	Poona	,, ...	42·05	·774
258—04	Sholapur	,, ...	44·45	·835
271—04	Dharwar ..	,, ...	41·23	·669
323—04	Satara ..	,, ...	42·85	·731
453—04	Surat, ½ white ...	,, ...	43·40	·888
472—04	Poona, ...	,, ...	41·75	·746
		Madras Presidency.		
568—04	Karnool ...	Brown	41·49	·696
812—04	Ditto ...	,, ...	41·35	·687
813—04	Ditto ...	,, ...	41·71	·703
1048—04	Bellary ...	,, ...	40·46	·660
1053—04	Do. ...	,, ...	40·72	·682
		United Provinces.		
674—04	Cawnpore ...	Brown	42·87	·558
675—04	Ditto ...	"Red," brown ...	42·19	·537
928—04	Partabgarh ...	White	44·19	·613
929—04	Cawnpore ...	"Red," brown ...	44·55	·923
971—04	Partabgarh ...	,, ...	42·30	·619
972—04	Cawnpore ...	,, ...	42·28	·828
973—04	Ditto ...	,, ...	41·70	·803
974—04	Unao ...	,, ...	41·44	·775
975—04	Do. ...	,, ...	41·77	·743
		Bengal.		
497—04	...	Brown ...	41·40	·516
		Assam.		
406—04	Sylhet	Brown ...	42·06	·521

Among other authorities, Armsby[1] quotes 21·7% of oil as a minimum for flax seed and 35·6% as a maximum. Smetham[2] quotes the following :—

	Oil. Per cent.
Bombay Linseed	38·21
Morschanski	30·81
Black Sea	30·78
Riga	31·19
St. Petersburg	35·31
Alexandria	35·73

The Indian specimens that I have examined are thus richer on the whole than the produce of other countries.

[1] Manual of Cattle Feeding, p. 483.

[2] Variations in the composition and feeding value of purchased feeding stuffs, p. 7.

AVERAGE COMPOSITION.

	Punjab.	Central Provinces.	Bombay Presidency.	Madras Presidency.
Moisture	7·60	6·73	6·81	6·72
Oil	38·27	41·36	40·71	40·12
Albuminoids	14·86	18·50	19·74	19·07
Soluble Carbohydrates	29·17	24·62	24·23	24·94
Woody fibre	5·74	4·80	5·01	5·35
Soluble mineral matter	3·72	3·22	2·96	3·26
Sand	·64	·77	·54	·54
	100·00	100·00	100·00	100·00
Total Nitrogen	2·55	3·05	3·28	3·14
Albuminoid Nitrogen	2·38	2·97	3·12	3·05

PAPAVER SOMNIFERUM—(*Poppy seed*).

The same remark must be made in relation to this seed as applied to Bassia latifolia. The number of specimens is so small as to preclude any general conclusions regarding the amount of oil in this seed in different parts of India. The variations in the specimens examined were, however, very small.

Sample No.	District.	Oil. Per cent.	Weight of 100 seeds. Grms.
	United Provinces.		
670—01	Cawnpore	47·90	·031
671—04	Do.	47·58	·034
930—04	Do.	47·60	·037
976—04	Unao	47·32	·036
977—04	Do.	46·35	·035
978—04	Partabgarh	48·33	·033
979—04	Do.	48·66	·033
980—04	Cawnpore	48·20	·038
	Bengal.		
496—04	....	48·13	·034
	Burma.		
573—04	....	44·82	·035

RICINUS COMMUNIS—(*Castor Bean*).

Numerous specimens of this seed have been examined. The list includes thirty-nine from Madras, thirteen from Bombay, twenty from the United Provinces and twenty-five from the Central Provinces. The oil was determined in the kernel ; the percentage in the whole seed was calculated from this figure after

allowing for the shell. With very few exceptions, the oil varies in kernels from 60 to 70 per cent., and this variation may be considered small. As is well known, the size of this seed varies very much indeed, and this is shown by the last column of the statement. The weight per 100 seeds is as low as 9 grms. in one case, and as high as 59·7 in another—a difference far greater than occurs in other oil-seeds, and is indeed quite remarkable. The percentage of shell is, however, much more constant. Moreover, a high proportion of shell is not coincident with a small seed, and presumably the thickness of the shell increases slightly with the size of the seed.

Sample No.	Vernacular Name.	District.	Kernels. Per cent.	Shells. Per cent.	Oil in kernels. Per cent.	Oil in whole seed. Per cent.	Weight of 100 seeds. Grms.
		Madras Presidency.					
140—03	Large seed ...	Vizianagram ...	74·24	25·76	66·88	...	...
150—03	Small do. ...	Godavery ...	69·23	30·77	67·00	...	...
1230—04	Castor seed ...	Do. ...	69·95	30·05	67·07	46·91	22·3
1231—04	Do. ...	Do. ...	71·42	28·58	67·05	47·88	21·8
1317—04	Do. ...	Do. ...	70·79	29·21	67·12	47·51	22·6
424—04	Do. ...	Kistna ...	70·61	29·39	67·81	47·88	21·1
663—04	Do. ...	Do. ...	69·80	30·20	67·01	46·77	19·8
569—04	Do. ..	Karnool .	69·62	30·38	68·96	48·00	31·6
816—04	Do. ...	Do. ...	66·66	33·34	67·95	45·29	20·4
817—04	Do. ...	Do. ...	69·43	30·57	70·69	49·08	22·9
1049—04	Chitamidalu ...	Bellary ...	68·01	31·99	69·19	47·05	17·7
1050—04	Paddamidalu ...	Do. ...	67·34	32·66	67·78	45·64	19·6
1054—04	Do. ...	Do. ...	67·19	32·81	67·59	45·41	18·9
1088—04	Castor seed, small	Do. ...	68·58	31·42	65·19	44·70	21·2
410—04	Castor seed ...	Anantpur ...	69·25	30·75	69·62	48·21	29·6
501—04	Do. ...	Do. ...	67·51	32·49	67·84	45·79	23·7
539—04	Do. big ...	Cuddappah ...	71·33	28·67	63·97	45·62	23·2
540—04	Do. small ...	Do. ...	61·66	38·34	57·46	35·42	9·0
449—04	Castor seed ...	Nellore ...	69·23	30·77	60·31	41·75	14·6
450—04	Do. ...	Do. ...	70·49	29·51	68·53	48·30	16·1
316—04	Do. ...	Salem ...	66·12	33·88	63·42	41·93	21·5
345—04	Do. ...	Do. ...	64·67	35·33	67·19	43·45	26·7
446—04	Do. ...	Do. ...	68·00	32·00	71·12	48·36	30·0
447—04	Do. ...	Do. ...	68·57	31·43	61·69	42·30	14·0
566—04	Do. ...	Do. ...	72·41	27·59	70·10	50·75	34·8
662—04	Do. ...	Do. ...	70·77	29·23	67·61	47·84	33·1
1035—04	Do. ...	Do. ...	68·81	31·19	69·67	47·93	31·1
1060—04	Do. ...	Do. ...	70·43	29·57	65·79	46·33	27·4
1061—04	Do. ...	Do. ...	69·92	30·08	67·43	47·14	33·2
1202—04	Do. large ...	Do. ...	70·68	29·32	64·62	45·67	30·7
1203—04	Do. small ...	Do. ...	66·39	33·61	67·20	44·61	18·1
1229—04	Do. ...	Do. ...	70·99	29·01	70·93	50·35	36·2
1417—04	Castor seed, big ...	Coimbatore ...	70·90	29·10	67·51	47·86	27·5
1418—04	Castor seed, small	Do. ...	65·75	34·25	63·16	41·52	14·6
1055—04	Sithamanakku ...	Madura ...	68·95	31·05	64·10	44·19	21·9
1056—04	Do. ...	Do. ...	67·77	32·23	62·51	42·36	18·0
1057—04	Periamanakku ...	Do. ...	62·34	37·66	56·22	35·04	39·3
1058—04	Do. ...	Do. ...	70·34	29·66	59·76	42·03	29·0
1059—04	Katamanakku ...	Do. ...	66·42	33·58	70·65	46·92	27·1

Sample No.	Vernacular Name.	District.	Kernel. Per cent.	Shells. Per cent.	Oil in Kernels. Per cent.	Oil in wholeseed. Per cent.	Weight of 100 seeds. Grms.
		Bombay Presidency.					
187—04	Castor seed ...	Ahmedabad ...	71·84	28·16	58·85	42·27	25·7
402—04	Do. ..	Kaira ...	72·30	27·70	64·50	46·63	37·2
459—04	Diveli ...	Surat ..	73·15	26·85	64·77	47·37	22·6
243—04	Castor seed ..	Nasik ..	73·24	26·76	55·24	40·45	40·8
249—04	Do. ...	Poona ...	74·08	25·92	64·41	47·71	41·9
460—04	Diveli ...	Do. ...	75·98	24·02	63·75	48·43	45·8
256—04	Castor seed .	Sholapur ..	68·17	31·83	63·22	43·09	19·8
268—04	Do. ...	Dharwar ...	65·10	34·90	65·69	42·76	16·0
326—04	Do. ...	Satara ...	73·05	26·95	61·30	44·77	37·3
475—04	Do. ...	Bijapur ...	72·43	27·57	65·43	47·39	37·0
1175—04	Do. ...	Belgaum ...	70·82	29·18	71·95	50·95	42·8
1179—04	Do. ...	Do. ...	74·36	25·64	63·87	47·49	31·2
1183—04	Do. ...	Do. ...	69·05	30·95	65·41	45·16	23·2
		United Provinces.					
676—04	Castor seed, large ...	Sultanpur ...	71·35	28·65	68·46	48·84	55·3
677—04	Castor seed, large ...	Do. ...	69·97	30·03	66·46	46·52	58·9
678—04	Castor seed, small ...	Do. ...	69·05	30·95	64·45	44·50	19·4
679—04	Castor seed, small ...	Do. ...	70·62	29·38	64·28	45·39	21·5
931—04	Randi, large...	Cawnpore ...	70·33	29·67	65·66	46·17	36·4
932—04	Do. small..	Do. ...	67·98	32·02	65·77	44·77	20·1
981—04	Do. large...	Do.	73·01	26·99	61·89	45·18	34·4
988—04	Do. small...	Do.	71·42	28·58	64·13	45·80	20·3
982—04	Do. large...	Partabgarh ...	60·49	39·51	64·20	38·83	40·8
983—04	Do. ...	Do. .	46·95	35·05	64·12	41·64	38·8
989—04	Do. ...	Do. ...	67·50	32·50	66·27	44·73	20·0
990—04	Do. ...	Do. ...	68·50	31·50	65·56	44·90	20·0
984—04	Do. ...	Aligarh ...	73·71	26·29	62·92	46·37	45·6
985—04	Do. ...	Do. ...	72·48	27·52	64·38	46·66	47·8
991—04	Do. ...	Do. ...	68·65	31·35	62·71	43·05	20·1
992—04	Do. ...	Do. ...	67·96	32·04	63·33	43·03	20·6
986—04	Do. ...	Unao ...	71·71	28·29	66·43	47·63	46·6
987—04	Do. large...	Do. ...	72·09	27·91	67·60	48·73	50·6
993—04	Do. ...	Do. ...	67·06	32·94	65·62	44·00	16·7
994—04	Do. ...	Do. ...	68·02	31·98	65·97	44·87	17·2
		Central Provinces.					
107—04	Undi ...	Jabalpur ...	73·60	26·40	60·69	44·66	59·7
117—04	Do.	Hoshangabad	70·60	29·40	60·72	42·85	43·5
544—04	Badi Andi ...	Do. ...	72·33	27·67	63·46	45·90	55·3
119—04	Castor ...	Nimar ..	70·14	29·86	61·42	43·07	69·0
134—04	Do., large ..	Damoh .	72·72	27·28	62·93	45·76	46·7
135—04	Do., small...	Do. ...	69·56	30·44	60·70	42·22	14·2
161—04	Andi ..	Raipur	59·14	40·86	62·03	36·68	12·9
169—04	Jada .	Sambalpur ...	70·02	29·98	65·09	45·57	19·5
177—04	Castor ...	Do. ...	68·50	31·50	65·58	44.93	18·0
195—04	Kachhari ...	Balaghat ...	69·72	30·28	64·95	45·28	32·0
196—04	Wevri ..	Do. ...	73·11	26·89	67·98	49·70	42·6
208—04	Castor ...	Narsingpur	71·20	28·80	61·16	43·54	25·3
226—04	Do. ...	Chanda ...	69·00	31·00	62·00	42·78	27·5
227—04	Do. ...	Do. ...	68·44	31·56	64·49	44.13	23·1
228—04	Do. ..	Do. ...	63·38	36·62	64·09	40·62	23·9
229—04	Do. ...	Do. ...	69·03	30·97	61·35	42·34	26·0
545—04	Yerandi .	Wardha ...	66·14	33·86	58·39	38·61	12·8
550—04	Do.	Do. ...	74·93	25·07	63·80	47·80	50·3
576—04	Andi Badi ...	Chhindwara ..	67·30	32·70	69·46	46·74	41·6
577—04	Do. Chhoti..	Do. ...	71·23	28·77	64·21	45·73	23·8
706—04	Yendi ...	Betul ...	70·92	29·08	64·36	45·64	24·3
915—04	Castor, large...	Bilaspur ...	73·61	26·39	64·82	47·71	53·5
916—04	Do., small...	Do. ...	64·03	35·97	64·63	41·38	15·8
1223—04	Andi Badi ...	Nagpur ...	72·91	27·09	63·07	45·98	49·0
1224—04	Do. Chhoti...	Do. ...	71·21	28·79	65·83	46·87	27·1

AVERAGE COMPOSITION.

	Madras.	Bombay.	Central Provinces.	United Provinces.
Moisture	4·85	4·11	3·98	4·17
Oil	63·62	56·71	63·72	63·22
Albuminoids	18·15	20·75	20·88	19·36
Soluble Carbohydrates	8·88	14·46	7·52	8·98
Woody fibre	1·53	·95	1·03	1·02
Soluble mineral matter	2·92	2·87	2·72	3·01
Sand	·05	·15	·15	·15
	100·00	100·00	100·00	100·00
Total Nitrogen	3·06	3·41	3·56	3·22
Albuminoid Nitrogen	2·90	3·32	3·34	3·10

Average proportion of shells and kernels :—

	Madras.	Bombay.	Central Provinces.	United Provinces.
Kernels, per cent.	68·79	71·81	69·88	69·34
Shells, per cent.	31·21	28·19	30·12	30·66

Composition of whole seed, calculated on the assumption that the shells are entirely indigestible "woody fibre" :—

	Madras.	Bombay.	Central Provinces.	United Provinces.
Moisture	3·34	2·95	2·78	2·89
Oil	43·75	40·70	44·51	43·93
Albuminoids	12·50	14·96	14·60	13·40
Soluble Carbohydrates	6·10	10·35	5·26	6·23
Woody fibre	32·26	28·87	30·84	31·37
Soluble mineral matter	2·01	2·06	1·90	2·08
Sand	·04	·11	·11	·10
	100·00	100·00	100·00	100·00
Total Nitrogen	2·10	2·44	2·48	2·23
Albuminoid Nitrogen	1·99	2·38	2·33	2·15

SESAMUM INDICUM—(*Vern. Til, Jinjelly.*)

	Area in British India. Acres.	Yield. Tons.
Grown as single crop	4,000,000	[1]300,000
Grown in mixed crop	500,000	

The specimens of this oil seed varied considerably in size and in colour, as well as in the amount of oil. The shape of the different seeds remains constant, but some are nearly twice as heavy as others ; the weight of 100 seeds varied from about ·18 to ·35 grammes in extreme cases and, excluding such exceptions, the

[1] This yield suffers great fluctuations from year to year.

variation may be said to be from ·22 to ·33 grammes. The *colour* is commonly either white, black, or brown, though some of the Central Provinces seed is more of a brick-red. Different specimens, however, vary much in colour between the limits named.

Most of the specimens were fairly free from admixture of earth, and they were quite free from seeds of other plants. On the other hand, no sample could be called pure, for there was invariably a greater or less quantity of varieties other than the predominating one ; in some cases the mixtures could not be designated by any colour in particular.

Regarding the percentage of oil, the variation is from about 48 to 52, though some specimens contained as much as 58 per cent., and some as little as 45 per cent. These variations appear to be independent of variety, Province or climate.

The specimens are arranged in the accompanying statement according to the colour of the seed as far as possible :—

Sample No.	District.	Province.	Oil. Per cent.	Weight of 100 seeds. Grms.
		White.		
13—04	Gurgaon	Punjab	46·49	·323
82—04	Kangra	Do.	53·06	·286
93—04	Umballa	Do.	51·12	·335
151—04	Rawalpindi	Do.	51·98	·280
75—04	Seoni	Central Provinces ...	49·38	·189
100—04	Jabalpur	Do. ...	47·31	·197
114—04	Hoshangabad	Do. ...	47·22	·250
121—04	Nimar	Do. ...	51·82	·282
129—04	Damoh	Do. ...	45·15	·224
173—04	Sambalpur	Do. ...	51·17	·233
198—04	Balaghat	Do. ...	52·43	·235
204—04	Narsingpur	Do. ...	48·64	·251
211—04	Chanda	Do. ...	52·45	·228
213—04	Do.	Do. ...	50·73	·231
290—04	Mandla	Do. ...	50·89	·215
186—04	Ahmedabad	Bombay Presidency ...	51·14	·319
247—04	Poona	Do. ...	51·22	·297
257—04	Sholapur	Do. ...	57·79	·286
253—04	Ahmednagar	Do. ...	55·27	·304
265—04	Kanara	Do. ...	55·57	·256
266—04	Dharwar	Do. ...	56·07	·339
		Black.		
18—04	Chenab Canal	Punjab	48·27	·357
87—04	Muzaffergarh	Do.	48·51	·378
67—04	Montgomery	Do.	46·41	·291
136—04	Sialkot	Do.	47·15	·313
101—04	Jabalpur	Central Provinces ...	47·37	·228
102—04	Do.	Do. ...	45·45	·232
199—04	Balaghat	Do. ...	50·44	·242
112—04	Hoshangabad	Do. ...	49·90	·274
205—04	Narsingpur	Do. ...	47·47	·263

Sample No.	District.	Province.	Oil. Per cent.	Weight of 100 seeds. Grms.
		Black—(concld.)		
130—04	Damoh	Central Provinces	45·45	·257
291—04	Mandla	Do.	47·56	·210
157—04	Raipur	Do.	49·07	·219
168—04	Sambalpur ...	Do.	50·77	·264
242—04	Nasik	Bombay Presidency ...	51·19	·337
264—04	Kanara	Do.	55·94	·318
269—04	Dharwar	Do.	54·50	·356
		Brown.		
8—04	Hissar	Punjab	48·71	·333
94—04	Umballa	Do.	47·92	·374
142—04	Gujrat	Do.	48·27	·320
289—04	Mandla	Central Provinces	47·61	·220
		Red.		
113—04	Hoshangabad ...	Central Provinces	53·01	·319
175—04	Sambalpur... ...	Do.	53·97	·347
214—04	Chanda	Do.	52·70	·315
215—04	Do.	Do.	51·86	·296
216—04	Do.	Do.	51·51	·326
218—04	Do.	Do.	50·94	·305
185—04	Ahmedabad ...	Bombay Presidency ...	52·79	·348
		White, Brown and Black mixed.		
120—04	Nimar	Central Provinces	53·52	·335
174—04	Sambalpur ...	Do.	51·54	·253
212—04	Chanda	Do.	49·98	·291
217—04	Do.	Do.	53·25	·242

The following illustrates the average composition of the seed :—

	White.	Black.	Brown.	Red.
Moisture	5·11	4·78	4·61	4·76
Oil	49·90	48·57	47·60	50·16
Albuminoids	16·25	18·93	18·73	18·50
Soluble Carbohydrates	17·79	15·88	16·41	15·69
Woody fibre	4·26	4·03	4·05	4·17
Soluble mineral matter	6·00	6·75	6·87	5·76
Sand	·69	1·06	1·73	·96
	100·00	100·00	100·00	100·00
Total Nitrogen	3·06	3·13	3·09	3·06
Albuminoid Nitrogen	2·59	3·03	3·01	2·96

THE EFFECT OF TRANSFERRING OIL-SEEDS TO ANOTHER PROVINCE.

It is known that the quality of a plant may be changed in one or another respect by transference to a different soil or climate. Thus it has been found that sugarcane may produce a poorer juice after such a change, though this is not universally the case.

After the oil-seeds had been tested, and it was known that some samples contained appreciably more oil than others of the same botanical order, specimens of the richer were in several cases grown at farms where seed of poorer quality was generally produced. Excepting in one case, the imported seed was not examined and only the newly-grown seed submitted to analysis. Although, in some cases, the latter was not so rich in oil as was the sample that had been originally tested in this laboratory, there was, strictly speaking, nothing to compare the newly-grown crop with. This precaution was, however, taken in the case of some linseed which was brought from different places to Lyallpur in the Punjab, and in the subjoined statement the percentage of oil in the original seed and in the crop is set out :—

	Original seed.	Produce of 1905.	Produce of 1906.
Linseed White from Cawnpore	44·62	41·28	39·90
Do. do. do. Khandwa	44·96	44·18	42·93
Do. do. do. Damoh	45·34	43·07	43·57
Do. Brown do. Partabgarh	43·17	40·98	38·31
Do. do. do. Cawnpore	42·05	40·97	39·43
Do. do. do. Sholapur	41·13	40·42	38·82

There has thus been a decline throughout. It remains to be seen whether this decline ceases, and whether after acclimatization the seed will regain its former richness or not.

THE POT-CULTURE HOUSE AT THE AGRICULTURAL RESEARCH INSTITUTE, PUSA.

By

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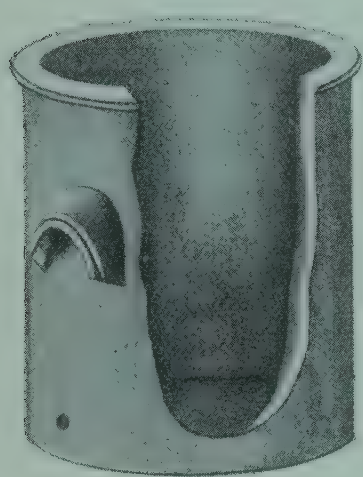
A Pot-culture House has been erected at the Agricultural Research Institute, Pusa, in Behar, and it is probable that a description of it, the apparatus employed, and the methods in use, may be of interest to others who utilize this means of investigation.

The Structure.—This includes two parts: the one being a masonry building in which operations may be conducted and plants grown at times when protection from sun and rain is desired, the other an enclosure protected from birds and large insects by wire-netting. The former has an area of 42 × 37 feet, the latter 42 × 47 feet.

The cultivation jars are placed on small trollies in the manner so common to these installations, and these trollies run on rails which extend through both enclosures. By means of a cross-rail, these trollies may be readily conveyed to any part of the building. The nature of the structure is shown in illustration No. 1. No. 2 shows the interior of the wire enclosure. Illustration No. 3 shows that portion of the house which is employed for mixing soils, introducing fertilizers, filling cultivation jars, or the execution of laboratory operations on a table. The floor is masonry. The table is fixed against the wall.

The Cross-rail Trolly.—Two patterns of cross-rail trolly are employed in different Institutes. The one (which is also common to the French railway system) runs on a rail on the same level as the general system, and the trolly is itself above the general level. This pattern is used in the Pot-Culture House at the Woburn Agricultural Station in England. The other pattern runs on rails *below* the general level, and the top of the trolly coincides with this. This pattern is used at Pusa. In the first instance the cross-rail was 13 inches below the ground-level, but as this proved an inconvenience when stepping across it, the axles were recently altered and the cross-rail raised to 6 inches from the ground-level as seen in Plate No. 4. It is indeed simple to construct a trolly which does not require the cross-rail to be more than about 4 inches below the ground-level, and the less this depression, the more convenient for the pedestrian.



No. 5, Cultivation Jar.

Cultivation Jars.—Both glass and stoneware cultivation jars from Europe have been used, but it was found that quite suitable ones could be obtained in India, and at a less cost. The illustration No. 5 shows the pattern which has been adopted. It has no projecting tubulure at the base, but merely a hole. Projecting tubulures are somewhat readily broken, and a simple hole in the jar is sufficient. Very generally, indeed, this is closed by a cork, as in most experiments no drainage occurs. The sizes employed are:—

	Inside depth.	Diameter.	Soil required to fill one jar.
	Inches.	Inches.	Kilos.
A	12	9	15
B	16	9	22
C	22	9	29
D	16	12	31
E	22	12	54

The smallest of these appears to be quite large enough for the perfect development of specimens of most of our field crops.

The Large Beam Scale.—Principally in order to maintain the proportion of moisture in soils as constant as possible, but also for other reasons, the jars of any experiment are weighed every day. For this purpose it is necessary to determine the weight with considerable precision. A differential scale is not sufficiently delicate for this purpose, and a plain beam scale which turns to five grammes with a maximum load of 100 kilos has been adopted. It is seen in illustrations Nos. 6 to 9. Its only peculiar feature is the pair of stirrups, or hooks, in which the jar rests when being weighed. A fruitful source of damage to large plants is the necessity for lifting jars by hand. Even the small ones are so heavy that the operator has to bend over the jar when lifting it, resulting not infrequently in broken plants, and the stirrups were designed in order to obviate this. When used, the trolly is brought to the scale, and the stirrups or hooks are placed on either side of the jar as in the illustrations Nos. 6 or 8; the beam is then depressed by hand until the stirrups will pass under either edge of the jar as in illustration No. 7, or the hooks under the handles (No. 9). The correct weights may then be placed on the pan. Weighing necessarily occupies some time, but as the jars can be dealt with at the rate of 30 per hour, this is not inordinately long, and admits of valuable information regarding loss of water, as well as the regulation of the moisture in the soil. In some cases it would be well to suspend the beam scale from a pulley on an overhead rail. For example, if two rows of jars are on a trolly, the weighing cannot be conveniently executed with a scale hung from a fixed point, but naturally the above arrangement would entail a slight extra expense.

Filling Jars.—The usual practice of experimenters in Europe is to fill the *dry* soil into the cultivation jars, and to add water afterwards at the surface. For many soils this procedure is doubtless sufficient, but for some, such as the fine alluvium of the Indo-Gangetic plain, I have found it inapplicable. When such soils are air-dry, they occupy a larger volume than when

damp, and the consequence is that, if water is added at the surface of a jar of such soil, cracks form which never fill up again, and subsequently added quantities of water are apt to pass straightway to the bottom. In order to obviate this, and indeed as a more perfect method of introducing water uniformly into soils, the filling is effected in the following manner. The weighed quantity of air-dry soil (after adding fertilisers where this is desired) is spread upon the floor. A measured quantity of water is then added from the mouthpiece of a wash bottle, or preferably from a funnel with "rose" attached, in such a way that the water falls on the soil in drops. After adding some of the water, the soil is turned over and any damp lumps broken down by hand. Further portions of the water are then added with alternate working by hand until the whole quantity is uniformly mixed with the soil. The following figures will illustrate the process. 15 kilos of air-dry Pusa soil, spread on the floor, received 1·46 kilos of water about one-fourth at a time. For this soil the quantity of water so introduced is about 10% of the soil. For other soils less or greater amounts of water are introduced, according to their nature. The aim is to introduce a quantity of water which will damp the earth, without, however, making it so damp that the clay could be "puddled" when the jar is filled.

The damped earth is now filled into the jar, and as each handful is introduced, it is levelled and pressed in quite firmly. It is difficult to explain in writing exactly how firmly, but the "doubled" or "clenched" hand is pressed down on it nearly as hard as the operator can do this, without in any way beating the soil. The method results in very uniform packing indeed, the variation being certainly less than 5% by volume between extreme cases, even when more than one operator fills a set of jars. By this method the earth becomes nearly as compact as in the field. In a set of jars recently filled, one cubic foot contained 76 lbs., whilst the subsoil of the locality contained 75 to 87 lbs. per cubic foot.

Addition of fertilisers.—Most substances, which it is desired to add, are introduced while the soil is in the air-dry state. The weighed substance is first mixed intimately with a small handful

of the soil on a board, and a further handful of soil is then mixed in also. This dry powdery material is then scattered uniformly over the main portion of dry soil lying on the floor and the mixture of the whole completed.

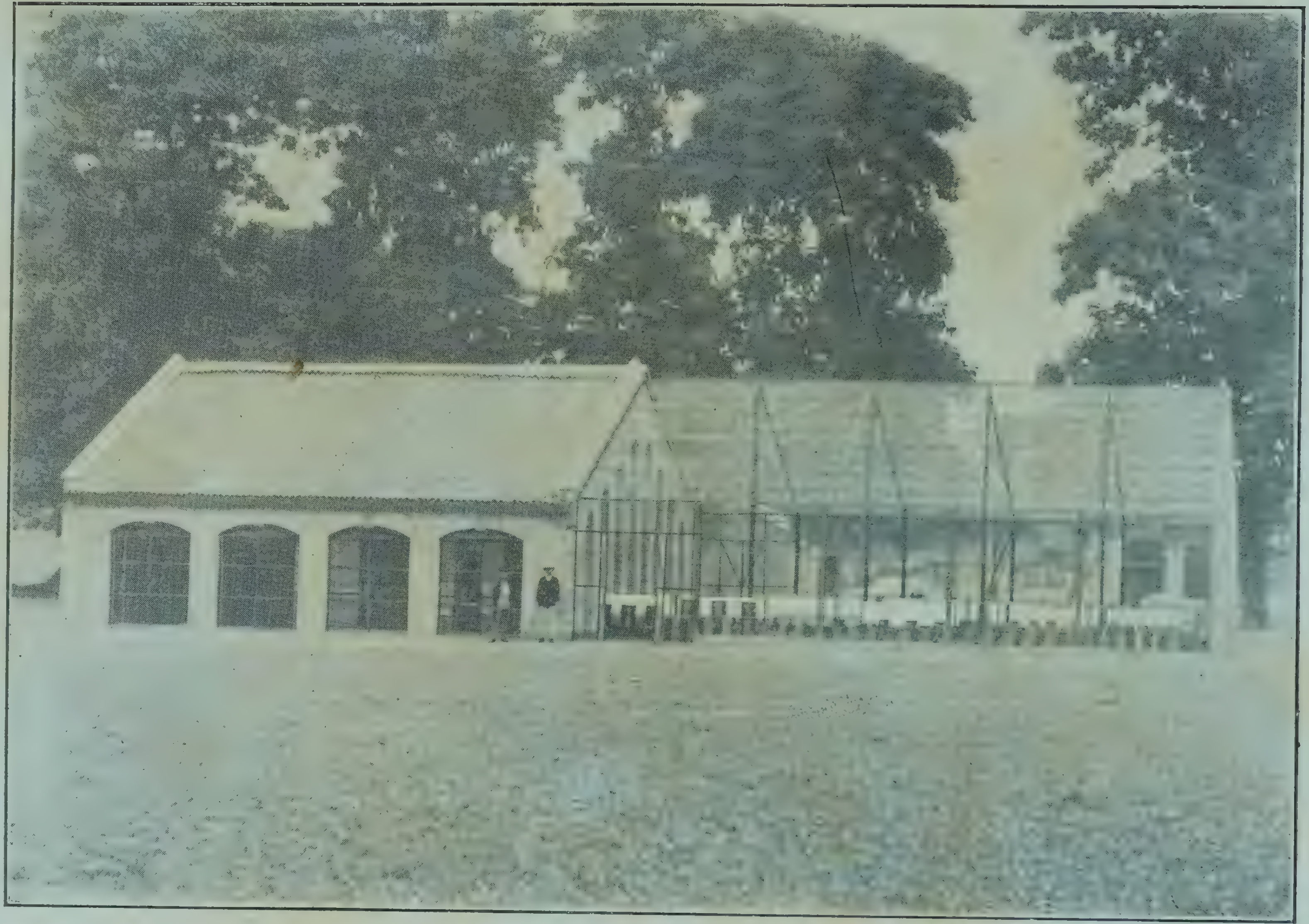
Nitrates are sometimes added to the growing plant in irrigation water, but in other cases such substances are added to the soil as described.

Addition of water.—Experimenters have employed various methods of adding water. By some it is simply poured on to the surface; by others it is introduced to the bottom of the jar by means of a tube, or more rarely through a porous cylinder placed vertically in the upper part of the soil. So far as I am aware, the latter has generally proved a failure. The addition of water at the surface of some Indian soils had, however, been so productive of cracking and caking, that experiments were made during the cold weather of 1905-6 to determine whether the water could not be introduced below the surface, so as to preserve this in an "open" condition. Both deep and shallow jars were employed, and three formed a unit. To one the water was added at the surface, to the second it was introduced by a tube to the bottom of the jar and into the third it was introduced by means of a porous cylinder. This latter method is very commonly employed to irrigate trees in India, in which case a porous spherical vessel is sunk in the ground near the base of the tree and kept full of water. The same weight of water was always added to the three jars of any one set. No manure was employed. The plants (oats) were reduced to 10 in each jar after germination, and afterwards to five, and from the weight of the thinnings an estimate was made of the rate of growth; finally, the weight of the harvested plants was obtained. The result is shown diagrammatically (chart No. 10), and it is clear that, at least for this soil, there can be no doubt about the great advantage of introducing water below the surface. The jars to which water was added at the base produced the most, those to which it was introduced through the porous cylinders came next, and, thirdly, those irrigated at the surface. A difficulty was indeed experienced in adding

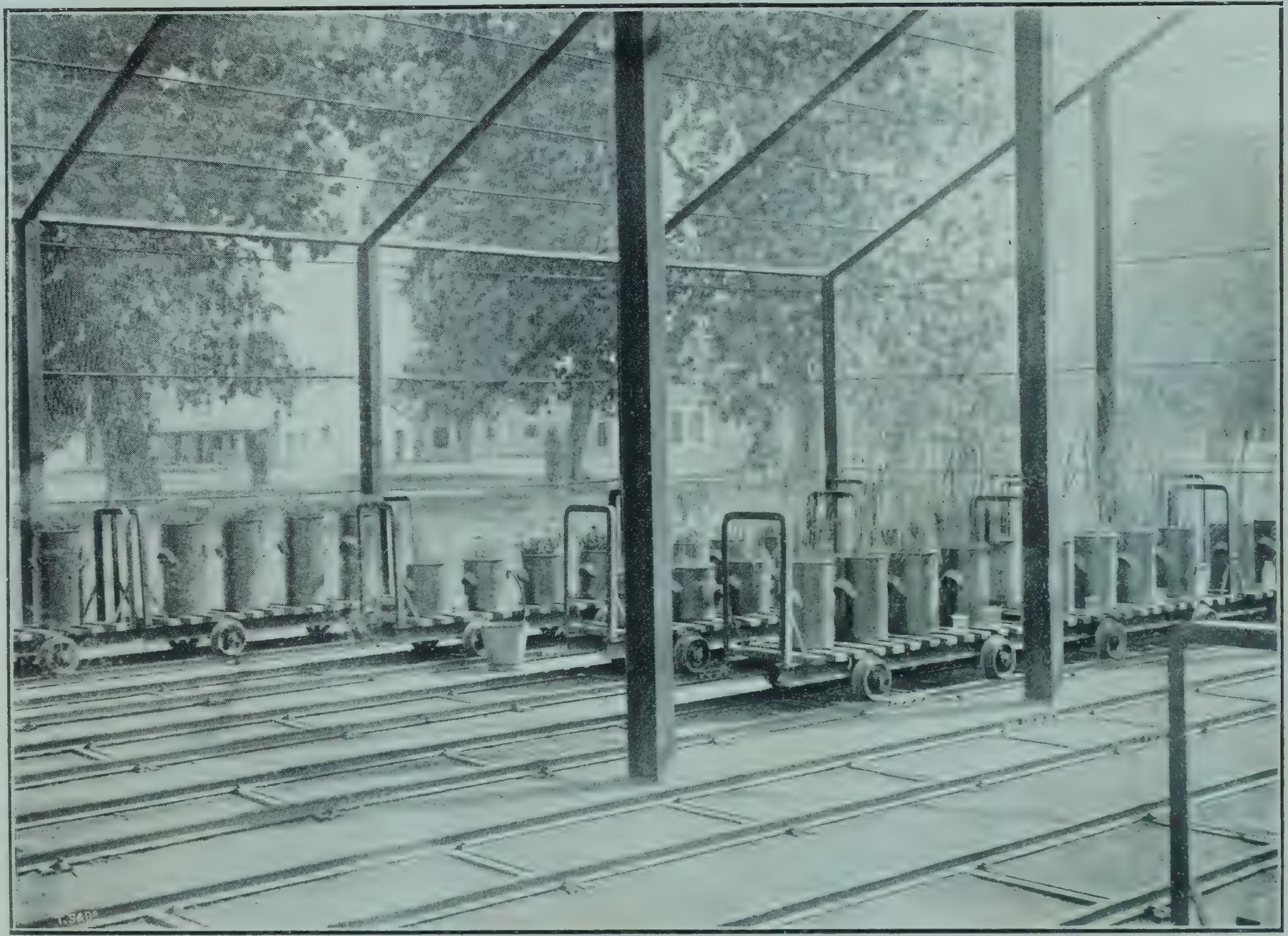
water quickly by either of the former methods, because it percolated very slowly not only through the porous cylinders but also into the soil at the base of the jars. Moreover, the latter method necessitated the use of a funnel and tube which were inconvenient.

For the present, porous cylinders are employed, and in order to admit of the more expeditious percolation of the water, they are pierced with small holes in the side, and are also made as large as is compatible with the size of the jars. The quantity of water transpired by plants when growing vigorously is considerable—a dozen young wheat plants may transpire upwards of one kilogramme per day, and usually the whole of this cannot be re-introduced into the soil in less than a couple of hours. The result is, however, entirely satisfactory so far as the surface soil is concerned, since it retains its loose pulverulent character and cracks and caking are avoided even when the proportion of water is maintained at 20%.

Thinning.—More seeds are usually sown in the first instance than the number of mature plants ultimately required. This is in part necessary since faulty germination is so frequent. But in addition to this, surplus plants provide a means of forming an estimate of the weight of the plants during the initial period of an experiment. After the young plants have fairly established themselves, the number may be reduced, and those which are cut out, weighed; from which the above data are calculated. Discretion is naturally used as to which plants are cut out, and these may be smaller than those remaining, so that the estimate involves some inaccuracy, but with good seeds, producing uniform germination, this source of inaccuracy is very small. Thinning is more particularly useful, for annuals, during the earlier stages of growth, before the plants have tillered much; if done later, the remaining plants will not develop more than if the number had not been reduced.

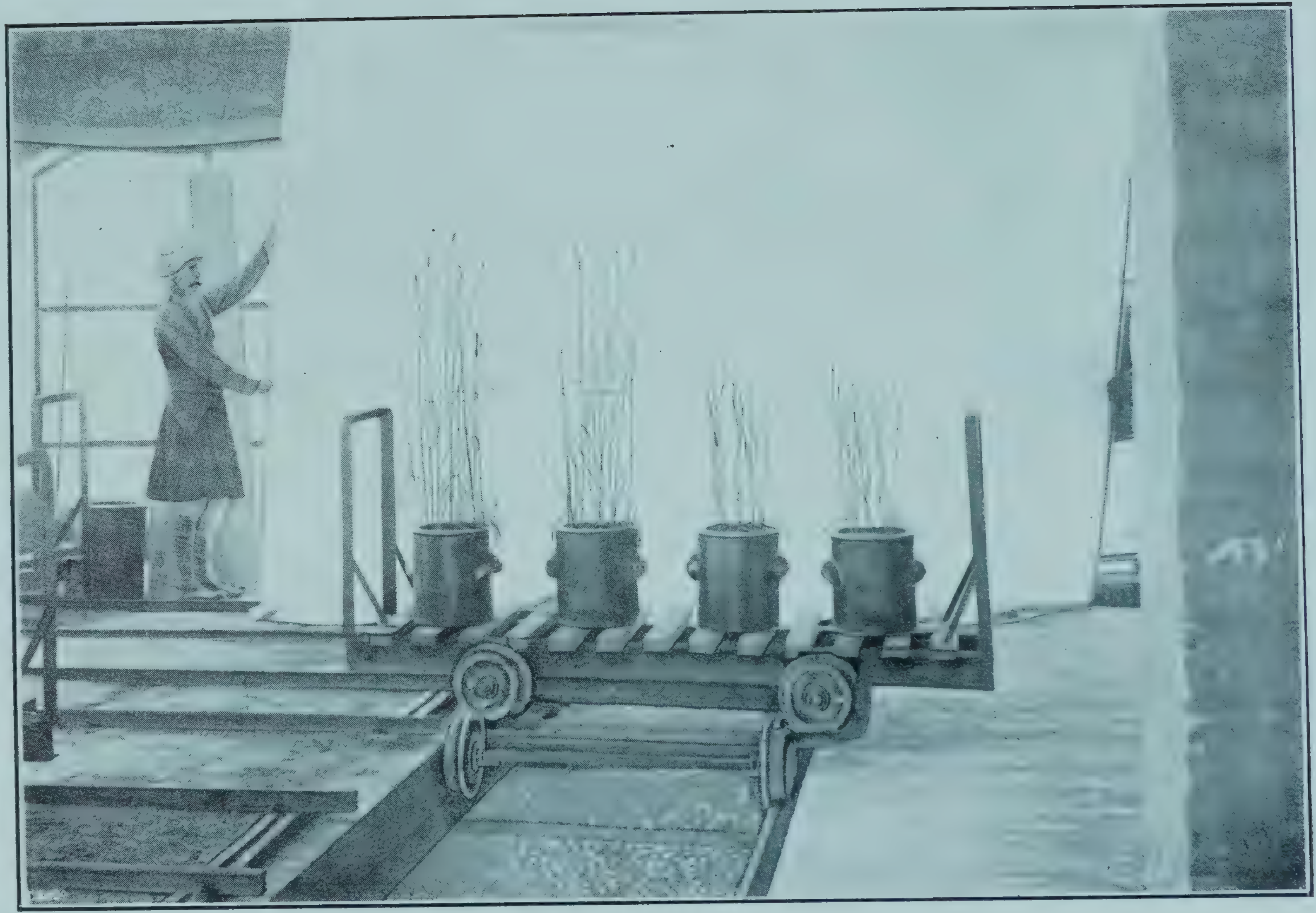


No. 1. The Pot Culture House.

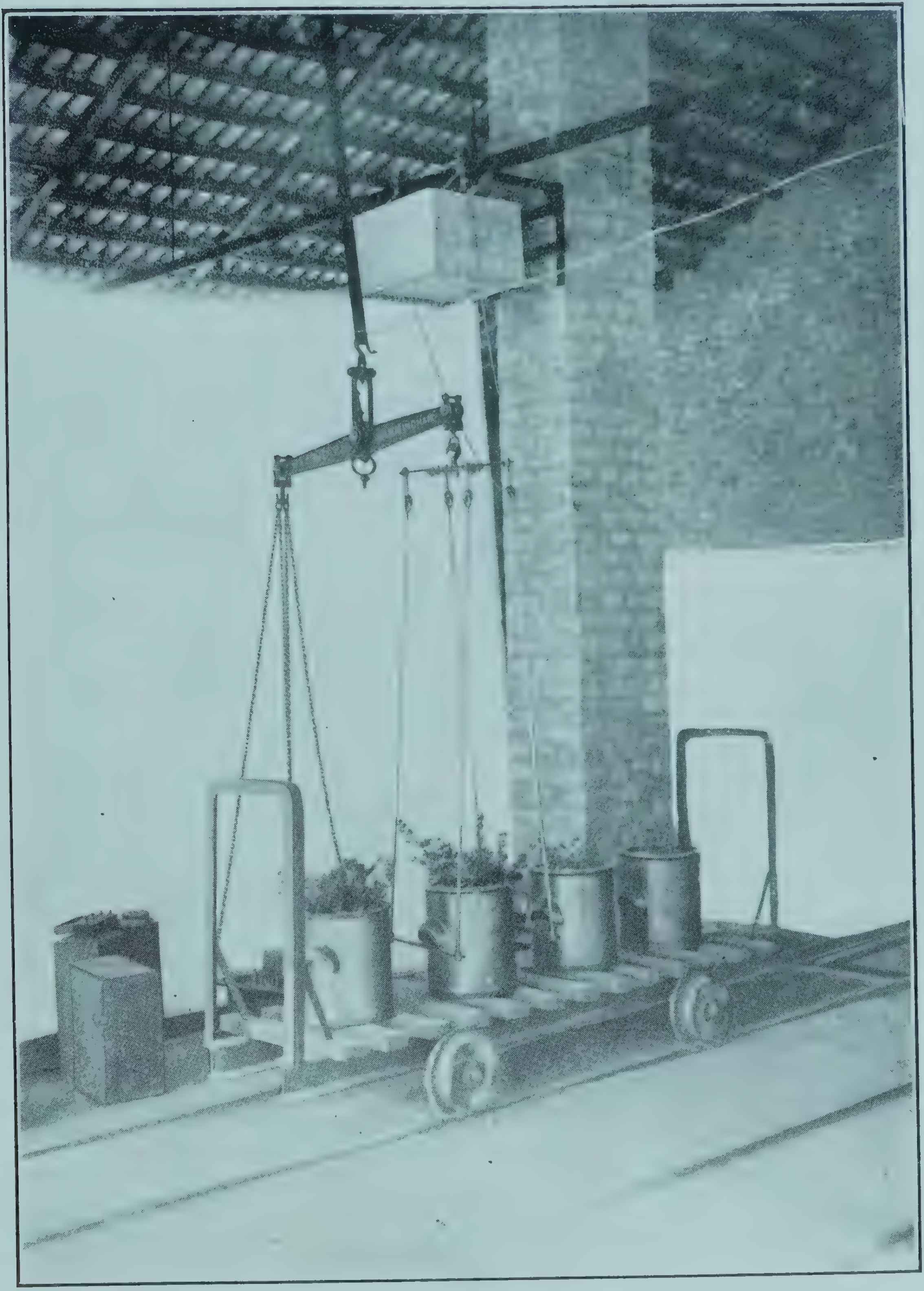


No. 2. Interior of Wire enclosure.

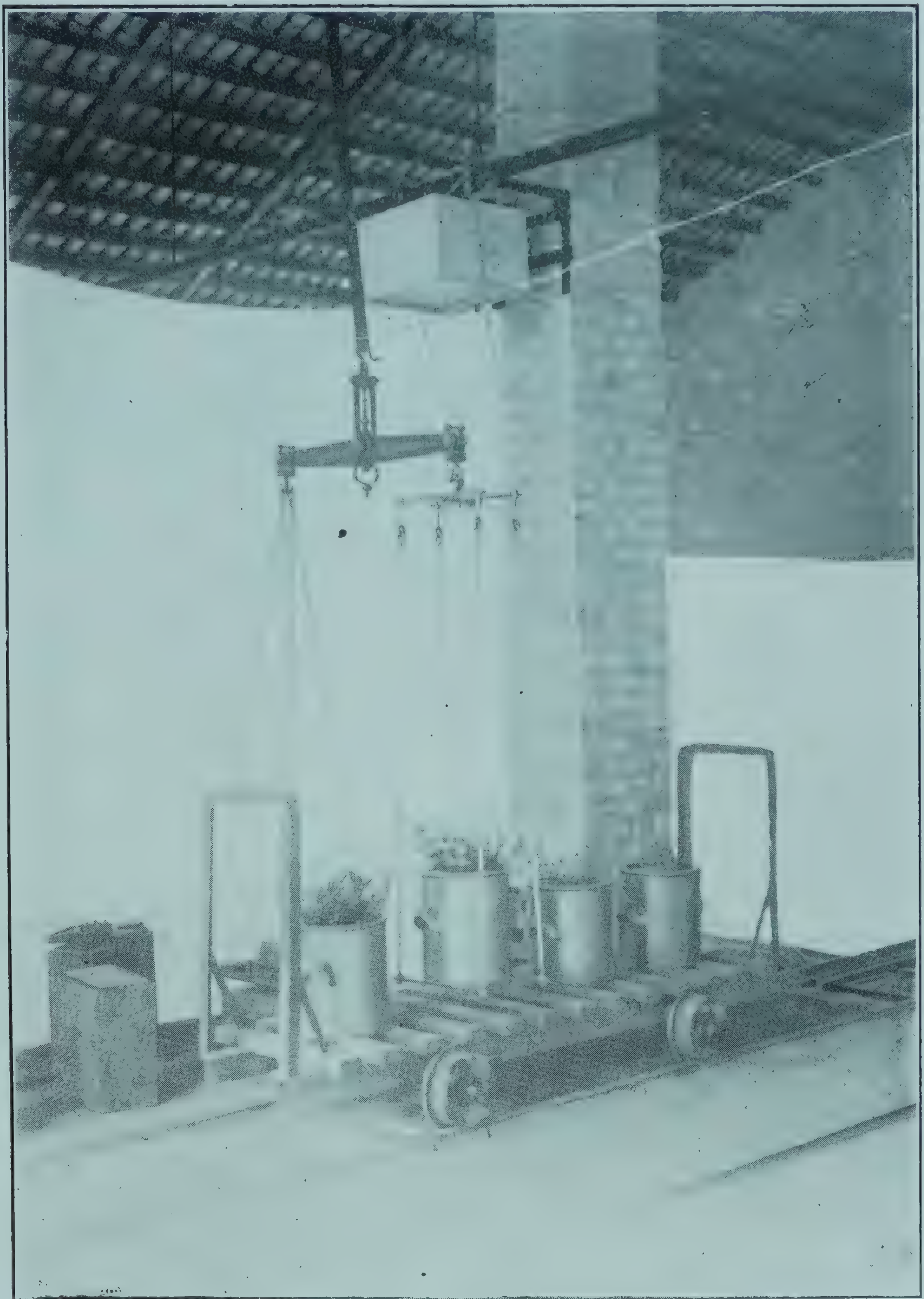
No. 3. Interior (Laboratory end).



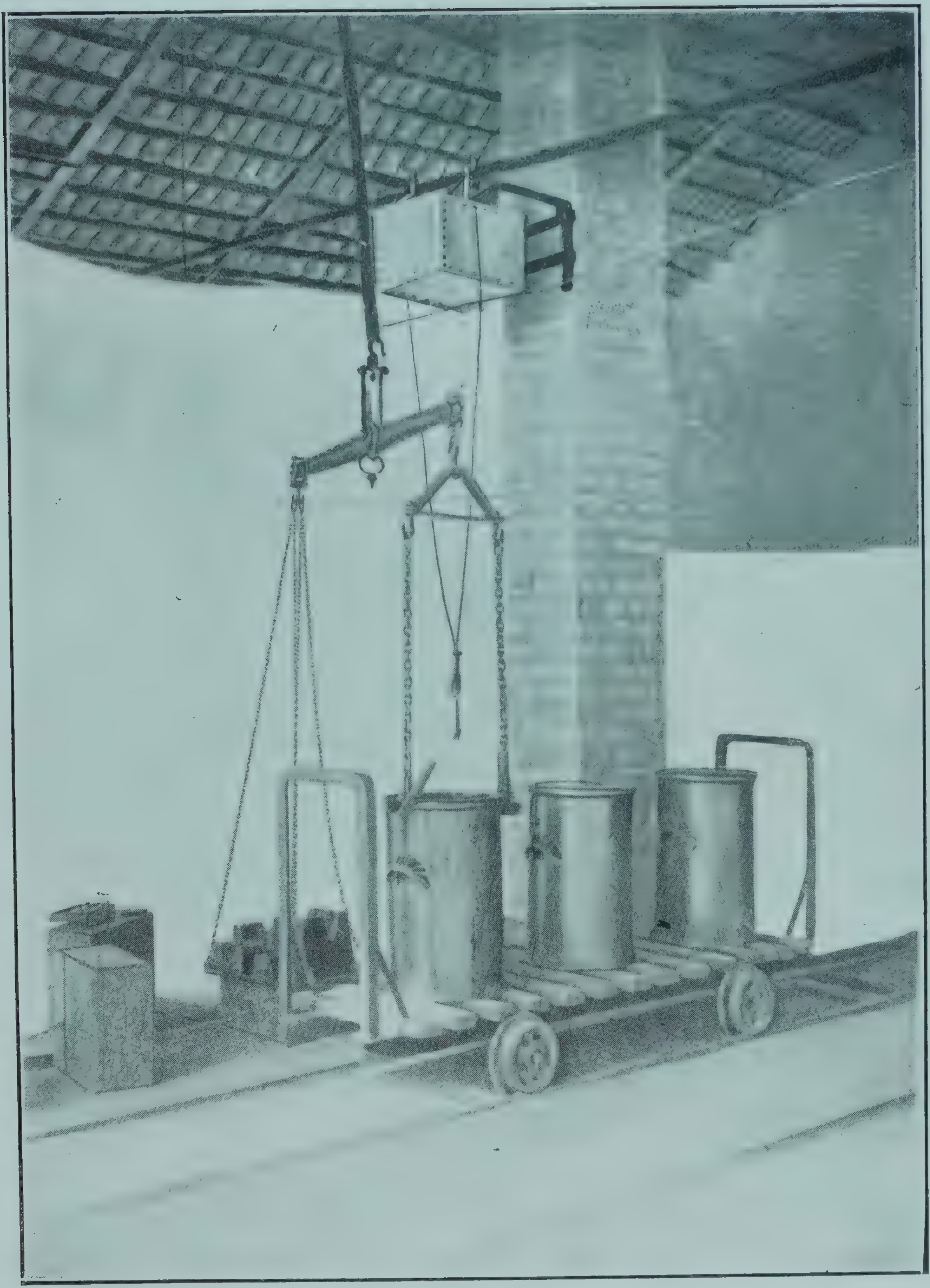
No. 4. The cross-rail trolly.



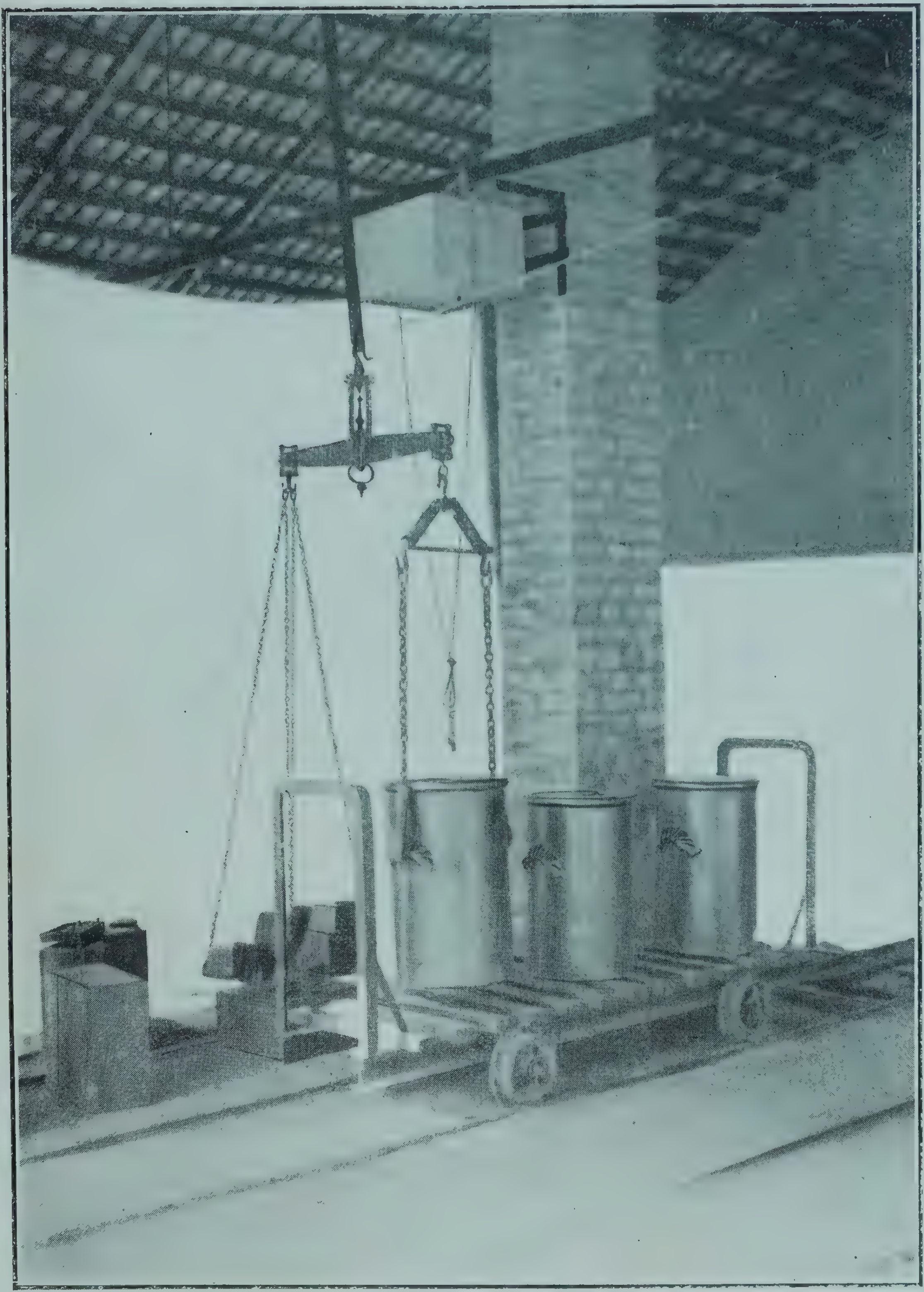
No. 6. The beam scale, showing the stirrups before being placed under the jar.



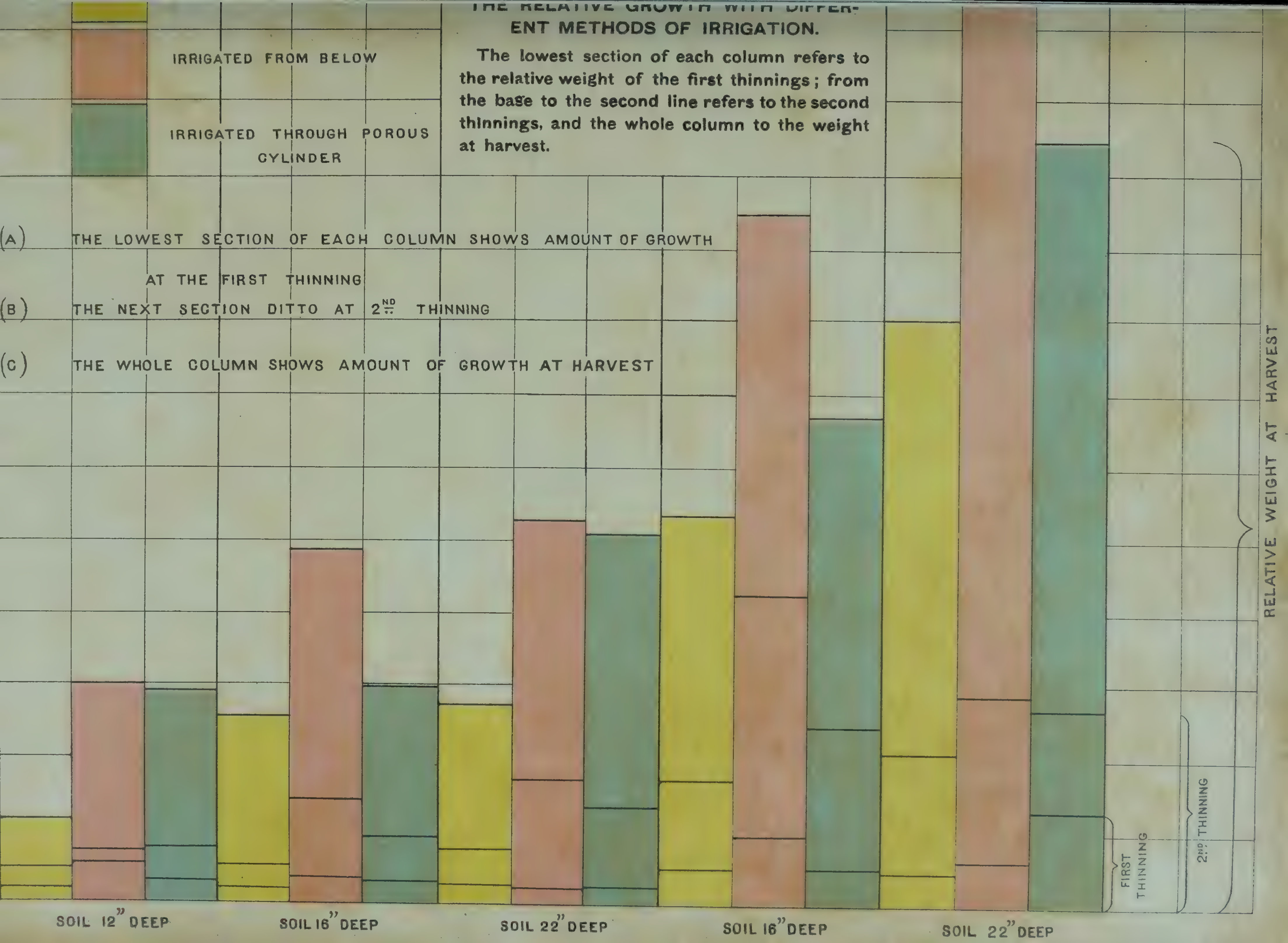
No. 7. The beam scale, showing the jar resting in the stirrups.



No. 8. The beam scale, showing the hooks before attachment to the jar.



No. 9. The beam scale, showing the jar resting in the hooks.


ENT METHODS OF IRRIGATION.
The lowest section of each column refers to the relative weight of the first thinnings; from the base to the second line refers to the second thinnings, and the whole column to the weight at harvest.
IRRIGATED FROM BELOW
IRRIGATED THROUGH POROUS CYLINDER
(A) THE LOWEST SECTION OF EACH COLUMN SHOWS AMOUNT OF GROWTH AT THE FIRST THINNING
(B) THE NEXT SECTION DITTO AT 2ND THINNING
(C) THE WHOLE COLUMN SHOWS AMOUNT OF GROWTH AT HARVEST
SOIL 12" DEEP
SOIL 16" DEEP
SOIL 22" DEEP
SOIL 16" DEEP
SOIL 22" DEEP
FIRST THINNING
2ND THINNING
RELATIVE WEIGHT AT HARVEST

EXPERIMENTS ON THE AVAILABILITY OF PHOSPHATES AND POTASH IN SOILS.

BY

J. WALTER LEATHER, Ph.D., F.I.C., F.C.S.,

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DURING the years 1904 to 1906 plants have been cultivated by pot-culture methods, with and without the aid of fertilizers, in a number of soils which have been brought from different parts of India.

The principal object in view has been to test how far the chemical method, which was advanced by Dyer in 1894 for the estimation of a sufficiency or deficiency of phosphate or potash in soils (*vide* Trans. Chem. Soc., **65**., 115-167, and Philos. Trans. Royal Soc., Series B., Vol. 194, pp. 235-290) is reliable generally. This method consists in the digestion of the soil at room temperature in a 1 per cent. solution of citric acid for seven days, on six of which the mixture is agitated frequently The solution is then separated by filtration and the phosphoric acid and potash present in it determined. Although such a method is obviously empirical, Dyer standardized the value of its indications by means of a considerable number of soils of the Rothamsted Experiment Station, the agricultural value of which for certain crops is well known. The outcome of his work may be suitably quoted from the second of the papers named. "The probable limit denoting phosphatic deficiency for cereals seems to be, as deduced from this investigation, between ·01 and ·03 per cent. of citric-acid-soluble phosphoric acid in the surface soil. That is to say, a percentage as low as ·01 seems to denote an imperative demand for phosphatic manure, while as much as ·03 would seem to

indicate that there is no such immediate necessity. For root crops, especially turnips, the limit would probably be higher." (Page 269.) "In the paper on the Hoos Field barley soils a tentative conclusion was drawn that the percentage of citric-acid-soluble potash in surface soil, indicative of potash hunger for cereals, would probably be below ·005. On considering the results of the wheat soil analyses and other results obtained in the interim by other workers who have applied the method to other soils known from other experience to be responsive to the influence of potassium salts, the author would now be inclined to modify this conclusion by suggesting that when a soil shows as much as ·01 per cent. of citric-acid-soluble potash, by this process, it may be regarded as not demanding any special application of potassium salts." (Page 275.)

There is one point which must be referred to here. One of the first questions raised, after the publication of Dyer's first paper, was in relation to calcareous soils. Obviously the calcium carbonate present in soils will forthwith react with the citric acid resulting in the formation of calcium citrate and carbonic acid, and the soil is then in contact with a solution of these substances together with any excess of citric acid.

In order to illustrate the bearing of this point, the following figures show the quantities of calcium carbonate in a soil which neutralize each tenth part of the citric acid employed; or since 10 grms. of the acid are employed per 100 grms. of soil, the figures show the percentage of calcium carbonate neutralized by each 1 grm. of the acid.

Citric acid. Grms.	Calcium Carbonate. Grms.
1	1·43
2	2·86
3	4·29
4	5·72
5	7·15
6	8·58
7	10·01
8	11·44
9	12·87
10	14·30

Thus even if the soil contains so high a proportion of calcium carbonate as 7·15 per cent., one half the citric acid remains, and the majority of soils contain considerably less than this. The Rothamsted soil, on which Dr. Dyer worked, contains only about 3 per cent. of calcium carbonate, which would alter the composition of the acid solution in only a minor degree.

Two of the soils which have been included in my experiments contained, however, upwards of 40 per cent. of calcium carbonate, and the citric acid becomes in such a case entirely neutralized.

Dr. Dyer in a postscript to his first paper recommends that in such cases an additional quantity of citric acid corresponding to the quantity of calcium carbonate " might reasonably be added to the solution." If, however, this is done with these highly calcareous soils, the soil constituents are not merely exposed to a solution of citric acid, but citric acid plus a large amount of calcium citrate, and carbonic acid. And indeed an even more important circumstance is the fact that the particles of calcium carbonate are entirely dissolved. Phosphate, which in such a soil may be present in the interior of these particles, is thus brought into actual contact with the solvent, whereas the idea underlying the use of the solvent is, that it will only be in contact with phosphates which are exposed to plant roots or soil-aqueous-solutions, *i.e.*, to phosphates which are on the *exterior* of soil particles. It is hardly, therefore, to be expected that the same result will be obtained as if the soil particles remain as far as possible intact. The circumstance emphasizes a weak point in the method. The following figures show the difference in result obtained (*a*) by the use of the usual 1 per cent. solution, and (*b*) this solution plus the extra citric acid, respectively :—

	By 1 per cent. citric acid.		By sufficient citric acid to neutralize the calcium carbonate plus the usual 1 per cent.	
	P_2O_5.	K_2O.	P_2O_5.	K_2O.
Seeraha soil containing 41·6 per cent. $Ca\,CO_3$	·001	·008	·019	·043
Pusa soil ,, 38·63 ,,	·0003	·0062	·0015	·0085

It will be seen presently that the Seeraha soil is certainly much in need of phosphatic manure, and that potassium sulphate produced positive effects in some cases. The Pusa soil has proved to be much in need of phosphates. If then the extraction had been made with the extra citric acid, the analysis would have indicated a very doubtful requirement of phosphates in the Seeraha soil, and certainly no requirement of potash. The pot-cultures on the other hand leave no doubt that these soils respond to phosphatic manures, and the Seeraha soil probably to potash.

The literature on the subject includes two papers. One by T. B. Wood (Trans. Chem. Soc., 1896, **69**, p. 290), where evidence is produced, showing that the use of the extra quantity of citric acid would have given a result indicative of a sufficiency of readily available phosphates, when in fact the soil responded to phosphatic manures; the other by Cousins and Hammond (Analyst, 1903, **28**, 238), where the evidence indicates the desirability of using the extra citric acid. This latter evidence relates, however, to land bearing bananas, a crop so entirely different from cereals that a quite different "limiting figure" may be applicable.

It is unfortunate that the conclusions on the subject are so contradictory. It seems to me preferable to adhere to the use of the simple 1 per cent. solution, and if, when it is applied to any particular class of soils, the limiting figure for phosphate or potash, as proved by actual trials with plants, is shown to be different from that which Dyer deduced with the Rothamsted soils, to then adopt this particular limiting figure. It is to be recollected that the method is not merely empirical, but that a limiting figure which is applicable to one description of plant, will not necessarily apply to another plant of widely different botanical character, period of growth, root range, etc. Dyer himself emphasized that the limiting figure he found would not necessarily apply to other crops than cereals, and "that for root crops, especially turnips, the limit would probably be higher" (*vide* ante).

It must be held to be a matter for regret that nearly all who have proposed methods for the estimation of available plant

food, have employed an acid as the solvent. Such solvents necessarily attack the surface of the particles in a manner wholly different from the neutral solutions present in the soil, and as has been pointed out, dissolve up particles of calcium carbonate entirely, thus exposing plant food to the solvent, which in the soil is present in the *interior* of particles. No doubt the quantity of material, which a neutral solvent will dissolve, is much less than would be brought into solution by an acid solvent, and difficulties arise in the determination of such minute quantities, but the fundamental defect attaching to acid solvents nevertheless remains.

The soils which have been subject to experiment at Dehra Dun and (later) at Pusa, comprise the following :—

Soil.	Containing :—		
	Organic Nitrogen. %	Available. P_2O_5 %	Available. K_2O %
Dehra Dun	·181	·146	·022
Seeraha-Behar	·046	·001	·008
Pusa-Behar	·060	·0003	·006
Shillong G	·228	·011	·010
,, B	·193	·005	·012
Bangalore	·059	·0047	·0023
Godavari V	·071	·042	·010
,, R	·084	·011	·005

For cereals, which have so far been principally included, the Dehra Dun soil would be considered sufficiently well supplied with phosphates and potash, and the Godavari V soil probably so ; the other six soils would be expected to respond to phosphates, and four, namely, Seeraha, Pusa, Bangalore and Godavari R to potash.

The first two years' experiments were made while the chemical laboratory was at Dehra Dun, where the conditions for this class of work were in many respects opposed to accuracy. Only a thatched hut was available, and the cultivation jars had to be moved by hand ; nor was any means available for maintaining the moisture very constant, such we now have. But the chief obstacle

proved to be rats and squirrels, which could not be kept away at night and damaged in great measure many of the mature plants.

In some of these cases an estimate of the weight of the entire plants was obtained when their number was reduced in each jar, and these figures aid in drawing conclusions.

The experiments of 1906 made at Pusa were free from such untoward incidents and are in consequence more reliable.

The details are set out in the following pages, but a graphic summary may be here inserted. If the sign + is employed to denote a positive result, whilst the sign – a negative one, ± where the outturn of grain is negative, but that of total dry matter positive, and ? where the indication is doubtful, the nett results will be seen at a glance.

	Phosphate:		Potash:	
	Expected.	Realized.	Expected.	Realized.
Dehra-Dun	–	–	–	......
Seeraha Behar	+	+ + ± +	?	+ + ±
Pusa-Behar	+	+	+	......
Shillong G	+	– + +	–	+ + +
,, B	+	– – +	–	– – –
Bangalore	+	+ + +	+	– + –
Godavari V	–	– ± +	–	– – +
,, R	+	+ ± +	+	– ± ±

This representation shows that great dependence may be placed on Dyer's method, as also his limiting figure for phosphates even in soils of a widely different nature. In the whole list, the cultivations have yielded a contradictory result in two cases. The Shillong B soil should have been benefited by phosphates, and if dependence were placed on the experiments at Pusa (carried out with the more perfect appliances), this exception would disappear. The Godavari V soil should hardly have responded to phosphatic manures, whilst it has done so to a greater or less extent.

The effect of potash is similarly characterized by contradictory results in two cases. The Shillong G soil has shown a

positive result where it was hardly to be expected. Dyer's test yielded ·01% K_2O which is his limiting figure. The Bangalore soil should have given a positive result with potash manure, but has done so with only one crop out of three. It is always to be recollected that neither Dr. Dyer nor other experimenters have advanced this method as an absolute one for determining whether it will pay to apply specific fertilizers. On the contrary, it has been regarded as one which must necessarily be employed with some caution. Our knowledge of the nature of the phosphates and the potash compounds which actually exist in the soil is most imperfect, and, as Hall and Amos (Trans. Chem. Soc., 1906, **89**, p. 205), have pointed out, the amount of a soil constituent which passes into solution in a given time depends not only on its nature but also on its mass. Soils in different parts of India differ very widely in composition, and whilst we may apply the 1% solution to them without exception, it does not follow that the same limiting figure will apply equally to all. Finally, the nature of the plant which is grown must always play an important rôle in relation to this limiting figure.

Nevertheless, and although I make these several reservations, there cannot be any doubt that the method is proving generally useful for ordinary agricultural land, enjoying a rotation of crops, one of which is usually a cereal, and that the limiting figure proposed by Dyer is much more generally applicable than might have been expected.

The details of the experiments are set out in the following paragraphs.

Dehra Dun Soil.

This soil is derived from shale and limestone of the Himalayas and is a rich soil with excellent physical characteristics.

The chief analytical data are as follows :—

	Per cent.
$CaCO_3$	·41
Total P_2O_5	·366
Available P_2O_5	·146
Available K_2O	·022
Organic Nitrogen	·181

It was only employed in one season's experiments when wheat and gram were grown. The outturns were as follows :—

Manure.	Weight of whole crops (grms.).	
	1903-4 Wheat.	1903-4 Gram.
Nil	37·6	45·5
Nitrate	62·0	45·0
Nitrate and phosphate ...	64·3	43·0

The same is set out graphically on the chart No. 1.

The Seeraha Soil.

This soil is representative of a large area in Behar and possesses two chief characteristics ; firstly, it consists entirely of very fine material, and like the whole Indo-Gangetic alluvium contains no stones ; secondly, about one-third of it is chalk.

The following are the chief analytical data :—

$CaCO_3$	41·6
Total P_2O_5	·097
Available P_2O_5	**·001**
Available K_2O	**008**
Organic Nitrogen	·046

It was employed during four seasons, the crops being cereals in each case. The results are set out in the following statement and on chart No. 2, from which it is evident that both phosphate and potash had a definitely positive effect.

Manure.	Weight of whole crop (grms.).				Weight of grain (grms.).			
	1903-4 Wheat.	1904 Murwa.	1904-5 Wheat.	1906 Kodo.	1903-4 Wheat.	1904 Murwa.	1904-5 Wheat.	1906 Kodo.
Nil	2·4	13·3	4·6	24·7	·7	5·4	1·6	12·3
Nitrate	2·1	63·9	11·5	43·9	·6	20·4	6·4	22·7
Nitrate and phosphate ..	8·3	63·8	20·0	62·4	2·5	26·9	5·9	30·0
Nitrate, phosphate and potash	...	80·3	26·5	...	...	29·1	7·9	...

The Pusa Soil.

This is similar in all respects to the Seeraha soil, but was first included in the experiments in the rainy season of 1906.

The chief analytical data are as follows :—

$CaCO_3$	38·63
Total P_2O_5	·10
Available P_2O_5	**·0003**
Available K_2O	**·0062**
Organic Nitrogen	·060

The crop grown was Kodo (Paspalum scrobiculatum), and the yields were as follows :—

Manure.	Weight of whole crop (grms.).	Weight of grain (grms.).
Nil	41·4	18·7
Nitrate	69·8	20·8
Nitrate and phosphate ...	86·1	27·7

The chart No. 3 illustrates the same result. The same soil has been utilized for similar experiments during the current season, wheat being the crop, and the effect of phosphate is even more marked. The effect of potash was not tested in the rainy season of 1906, but judging by the present season's plants its effect will be negative.

Bangalore Soil.

This is derived from the laterite, and is consequently highly ferruginous. It holds only a low proportion of water. When wet, it drains readily, but at the same time contains so much plastic material, that it is adhesive when damp. The chief analytical data are :—

$CaCO_3$	·066
Total P_2O_5	·052
Available P_2O_5	**·0047**
Available K_2O	**·0023**
Organic Nitrogen	·059

Cultivations were made during three seasons, namely, the monsoons of 1904 and 1906 and the "cold weather" of 1904-05; the crops being Murwa (Eleusine coracana) in the former, wheat in the latter. The plants of the first two seasons were interfered with by the depredations of squirrels and rats, and ultimately the only dependable index of the effect of the manures was the estimated weight of green plants at the time the number of plants in each jar was reduced. It is clear that the phosphate had produced a positive effect at this time, and the cultivations of 1906, which were free from such errors as the above, leave no doubt of this. The effect of potash has been however much less certain, although one might have anticipated a positive result.

The weights of plants were as subjoined and the chart No. 4 refers to them also.

WEIGHT OF CROPS (GRMS.).

Manures.	1904 Murwa.	1904-05 Wheat.	1906 Murwa.
Nil	4·4	·51	10·6
Nitrate	4·15	1·66	39·1
Nitrate and phosphate ...	6·05	1·88	63·3
Nitrate, phosphate and potash	5·02	2·08	43·3

SHILLONG SOILS.

Two soils had been received from Shillong, the one being considered good, the other distinctly infertile. Examination in the chemical laboratory revealed nothing which would account for such a difference. Apart from other characteristics, they have proved to be very similar in their productive powers, and the difference noticed at the place of origin has not at any time exhibited itself in my experiments; both soils have proved to be very fertile. For purposes of differentiation their titles of "good" and "bad" have been retained. They are chiefly characterized by a high proportion of organic matter (3·09 per cent. organic

carbon) and great waterholding capacity. The chief analytical data are as follows :—

		"Good" soil.	"Bad" soil.
$CaCO_3$	...	·088	·025
Total P_2O_5	...	·069	·059
Available P_2O_5	...	**·011**	**·005**
Available K_2O	...	**·010**	**·012**
Organic Nitrogen	...	·228	·193

Murwa was cultivated in the monsoons of 1904 and 1906, and wheat in the cold weather of 1904-5. Like the corresponding plants of the Bangalore soil, these suffered from attacks by rats when the wheat was ripening, and the only index remaining of the effect of the fertilisers was the estimated weight of the green plants when the number in each jar was reduced. The effect of phosphates in these soils is doubtful, whereas it should have been positive in both. This may in part be due to the absence of nitrogenous manure. In other experiments it has frequently been observed that, even though a soil is deficient in available phosphate, a positive effect of this plant food will only be realized if a nitrogenous fertilizer is added at the same time. In such cases, however, there was likewise a deficiency of nitrogen in the soil, and the combined effect of the fertilizers has been just what is found on similarly characterized plots at Rothamsted and Woburn. But when these pot cultures were commenced, the anticipation was that the Shillong soils were so well supplied with nitrogenous organic matter that added nitrate would have little or no effect, and with the limited amount of soil available the distribution of fertilizers was made on this basis. Later, after the effect of the "complete" fertilizer was observed, it was too late to re-arrange the treatment. For several reasons the most reliable result is that obtained in the new pot culture house at Pusa, and with that season's experiment phosphate had a distinctly positive effect. I consider it probable therefore that the indication provided by the analytical method in 1903 was correct and that phosphates would generally react positively with

this soil. The yields are as subjoined and are also illustrated by chart No. 5.

SHILLONG SOILS.

MANURES.	"GOOD."			"BAD."		
	1904 Murwa.	1904-5 Wheat.	1906 Murwa.	1904 Murwa.	1904-5 Wheat.	1906 Murwa.
	Weight of whole crop (grms.).					
Nil	52·2	·36*	31·8	42·5	·57*	32·4
Phosphate	40·1	·56*	33·7	50·0	·53*	41·8
Potash	57·5	·45*	43·2	49·5	·54*	31·1
Phosphate, potash and nitrate	74·7	·80*	69·1	56·2	1·06*	74·4
	Weight of grain (grms.).					
Nil	16·7	...	12·0	15·1	...	12·9
Phosphate	16·1	...	16·8	15·6	...	17·5
Potash	19·2	...	16·2	14·7	...	11·6
Phosphate, potash and nitrate	30·0	...	26·5	19·7	...	28·6

* Estimated weight per plant on January 18th, 1905.

THE GODAVARI SOILS.

The soil of the Godavari Delta is largely black cotton soil of a very stiff tenacious type and is probably alluvium brought from the similar tracts of the Indian plateau. It was known that much of this land contained low proportions of lime and phosphate as determined in the laboratory, and sufficient earth was sent from two villages for three or four jars. But these portions contained rather more phosphate than was anticipated. The following are the analytical data :—

	Vadlamur.	Ragampeta.
Ca CO_3	·179	·134
Total P_2O_5	·143	·119
Available P_2O_5	**·042**	**·011**
Available K_2O	**·010**	**·005**
Organic Nitrogen	·071	·084

Cultivations were made during three seasons, and the yields are set out in the subjoined statement and on chart No. 6.

GODAVARI SOILS.

MANURES.	VADLAMUR.			RAGAMPETA.		
	1904 Murwa.	1904-5 Wheat.	1906 Murwa.	1904 Murwa.	+ 1904-5 Wheat.	1906 Murwa.
	Weight of whole crop (grms.).					
Nitrate	45·8	18·9	57·0	32·4	22·0	66·4
Nitrate and phosphate ..	29·8	22·2	83·0	28·9	29·0	83·0
Nitrate, phosphate and potash	41·0	23·9	89·1	28·0	26·0	77·2
	Weight of grain (grms.).					
Nitrate	7·5	6·0	24·9	5·2	6·2	31·6
Nitrate and phosphate ...	5·9	5·2	37·4	7·1	5·7	38·5
Nitrate, phosphate and potash	6·0	4·0	39·0	6·2	5·5	31·1

These soils have given the least dependable data of any in the series; "Vadlamur" should hardly have given a positive reaction with phosphate; "Ragampeta" should have done so. As the data show, they have both reacted similarly, the first crop was negative, the second doubtfully positive, the third distinctly positive. The latter, grown under the much more satisfactory conditions at Pusa, is the most reliable.

CHART No. 1.

DEHRA DUN SOIL.

RELATIVE YIELD OF TOTAL CROP

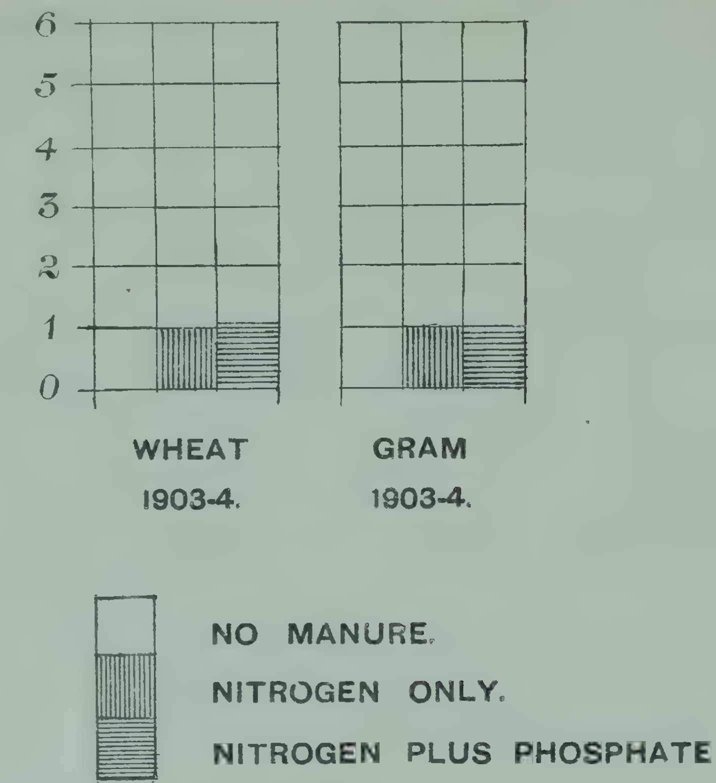
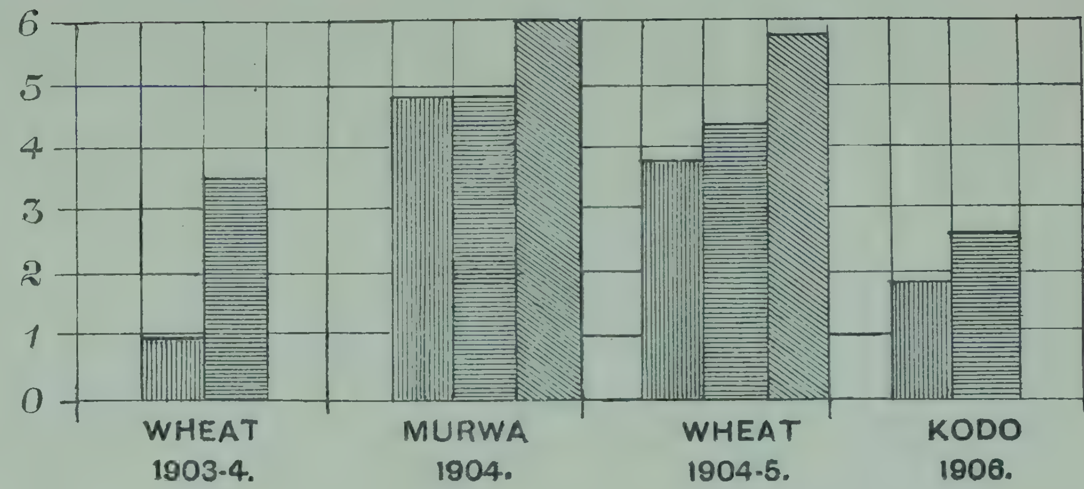


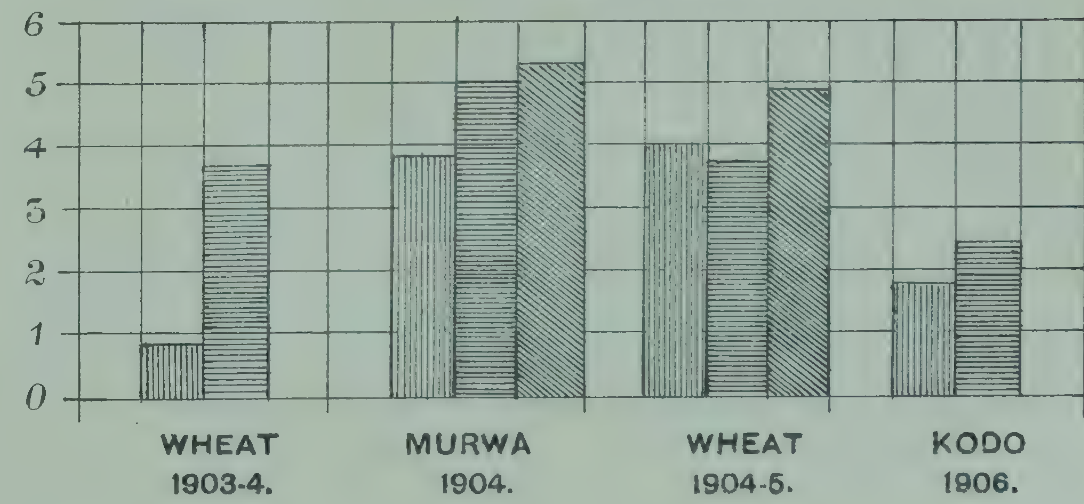
CHART No. 2.

SEERAHA SOIL.

RELATIVE YIELD—TOTAL CROP



RELATIVE YIELD-GRAIN.



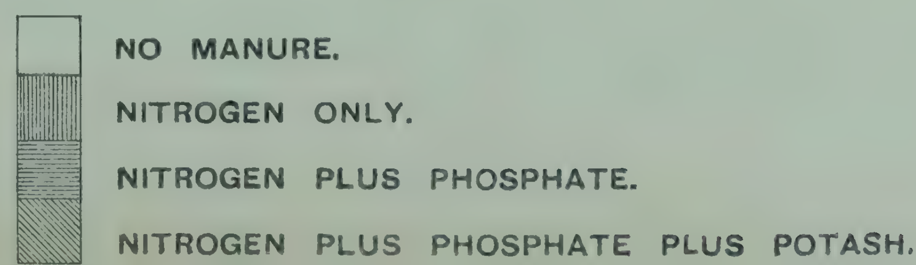
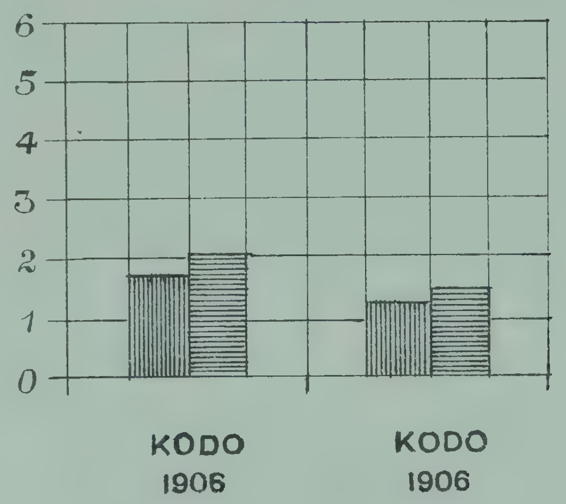


CHART No. 3.

PUSA SOIL.

RELATIVE WEIGHTS

OF TOTAL CROP OF GRAIN



NO MANURE.

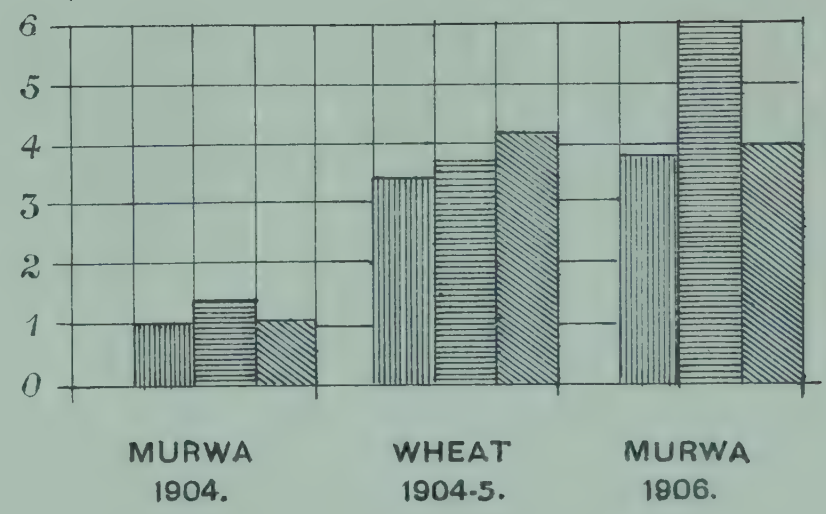
NITROGEN ONLY.

NITROGEN AND PHOSPHATE.

CHART No. 4.

BANGALORE SOIL.

RELATIVE WEIGHT OF TOTAL CROP



NO MANURE.

NITROGEN ONLY.

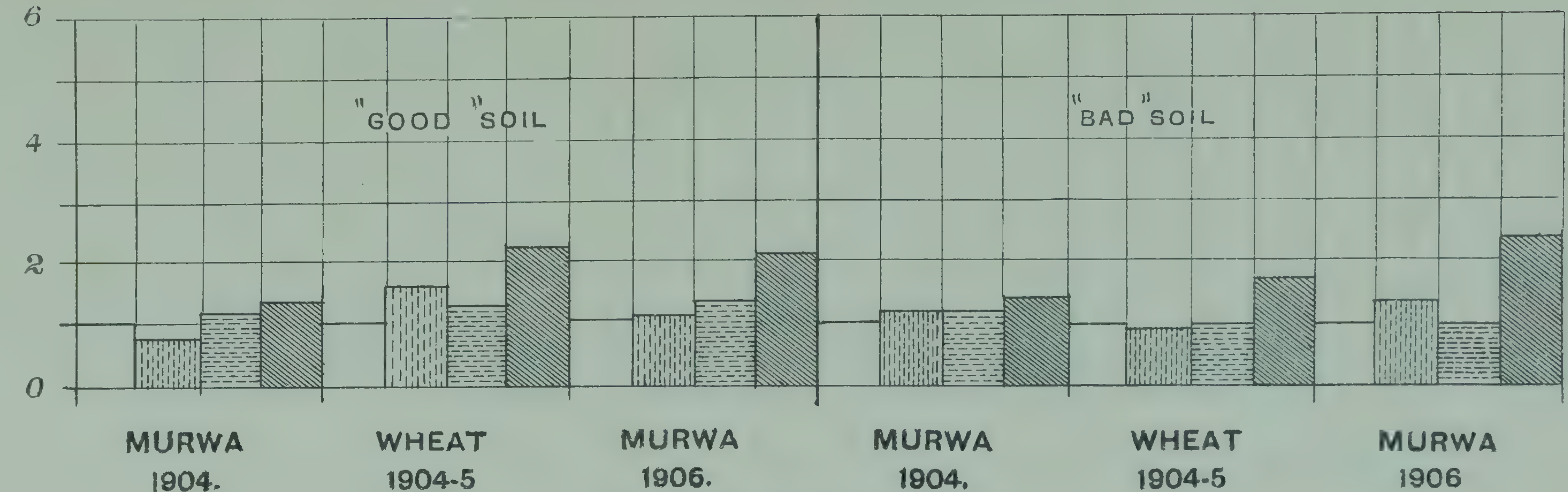
NITROGEN AND PHOSPHATE.

NITROGEN, PHOSPHATE AND POTASH.

CHART No. 5.

SHILLONG SOILS.

RELATIVE YIELD—TOTAL CROP.



RELATIVE YIELD—GRAIN.

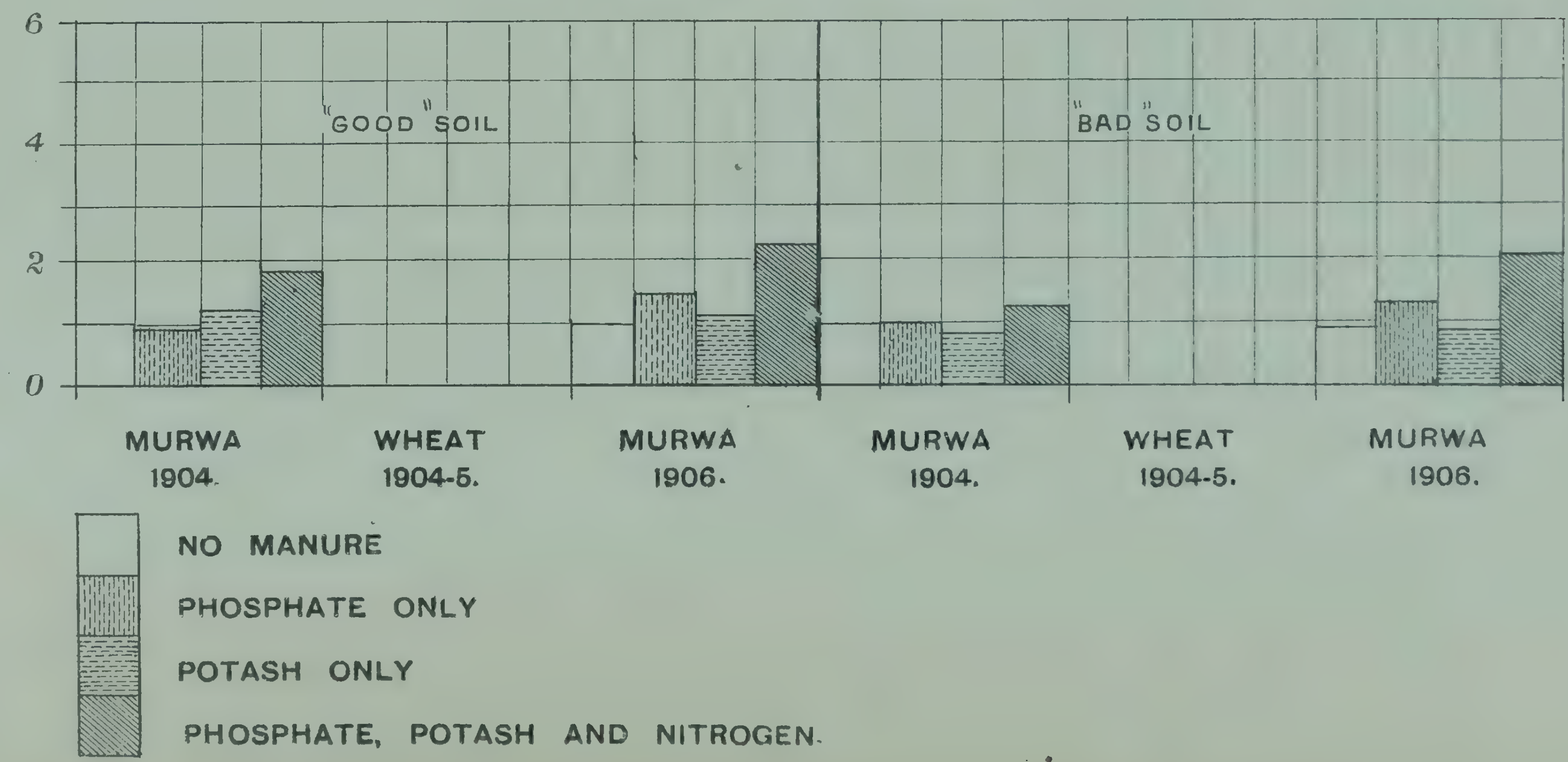
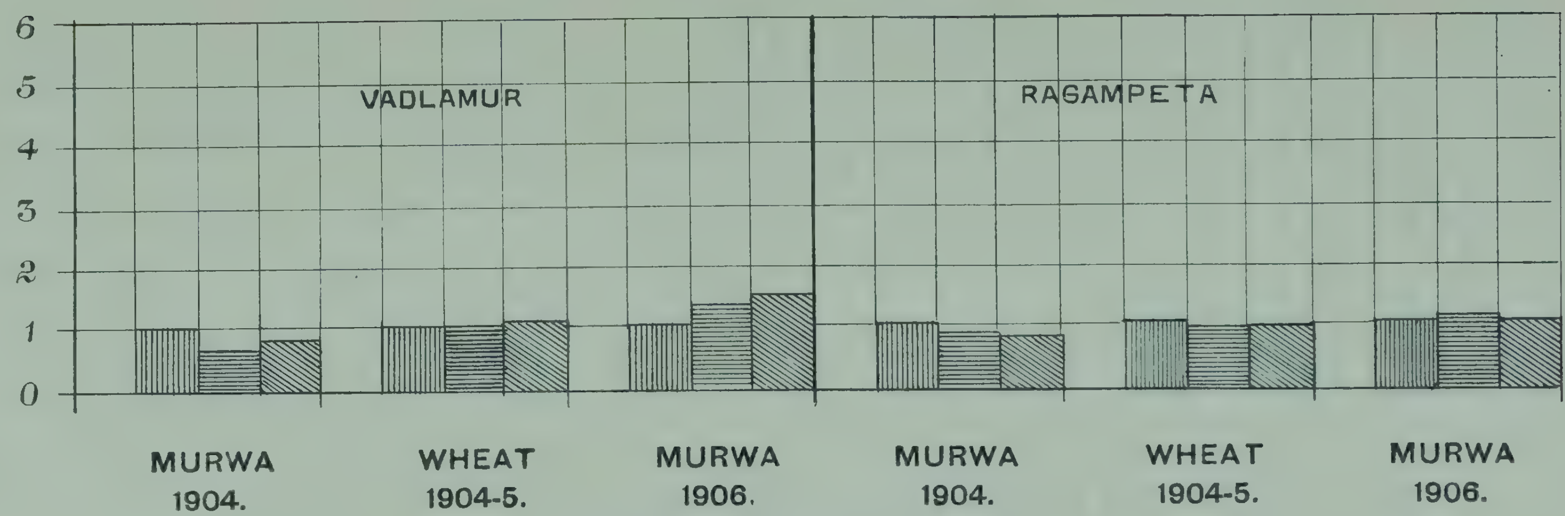


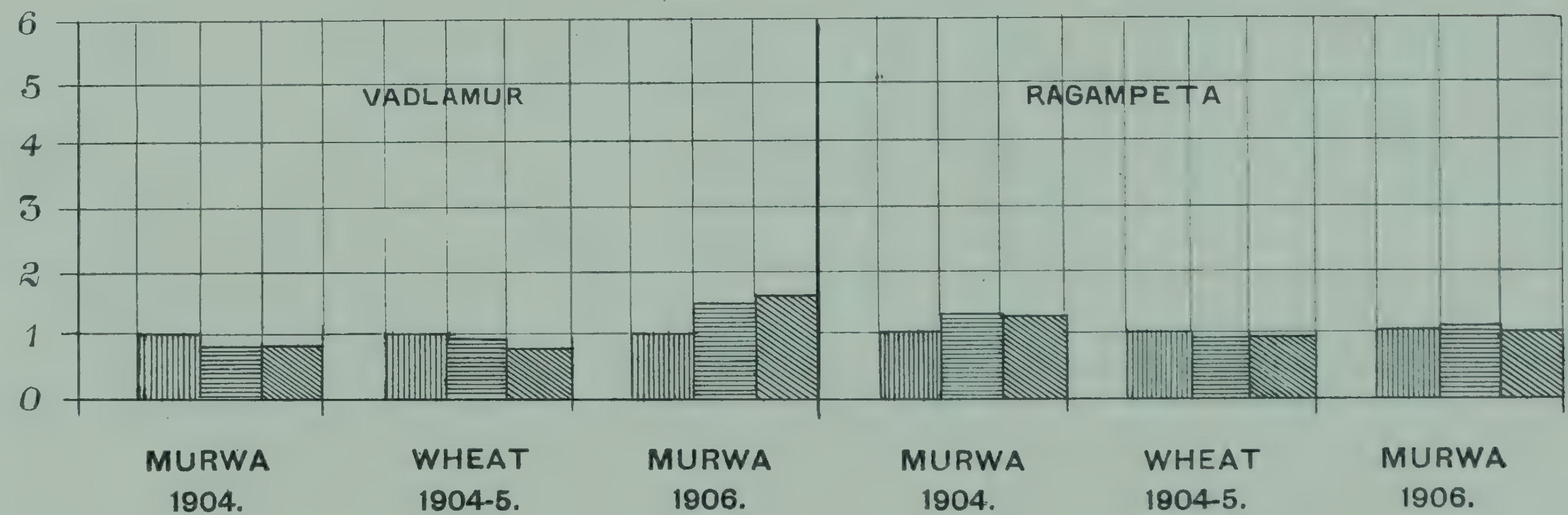
CHART No. 6.

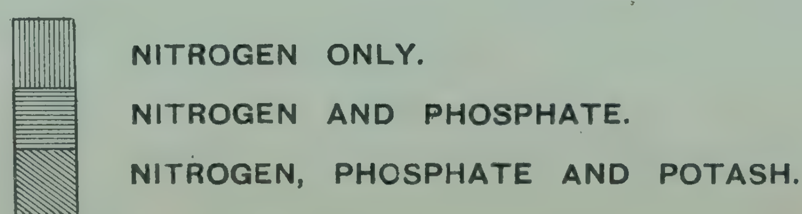
GODAVERI SOILS.

RELATIVE WEIGHT OF TOTAL CROP.



RELATIVE WEIGHT OF GRAIN.





THE LOSS OF WATER FROM SOIL DURING DRY WEATHER.

BY

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INTRODUCTORY.

The general idea regarding the movement of water in the soil during dry periods is that it rises by "capillarity," and since illustrations of this may be given by reference to such phenomena as oil rising up a lamp wick, no difficulty is experienced in obtaining a mental picture of the process. As a matter of fact, it is easy to show that any upward movement of water through the soil must be essentially different from that of the lamp oil. For, in the latter case, fresh oil rises up as fast as the upper portion burns off, and the wick is constantly saturated. Similarly, if one considers a capillary tube containing water; assume that the liquid can rise say x cm. into it; let the upper end be not more than x cm. above the supply of water, and then as fast as water vaporises from the upper end, more will flow upwards and the tube remains permanently full. The soil must be very differently situated, because we know that water does not rise through it "by capillarity" fast enough to replace the vaporised water. There must be some fundamental difference between the two cases. For a similar reason it is, indeed, of little use to experiment in the laboratory with columns of soil, even if these measure as much as two or three feet in height; the difference between this and ordinary field conditions where the subsoil water-level is usually more than 10 ft. and often more than 100 ft. below the surface, is so great as to render deductions from such experiments invalid.

Consider, for example, the experiments quoted by King in "The Soil" (page 174) where columns of soil were placed in water, the water-level being regulated at 1, 2, 3 and 4 ft. from the surface. Water was then found to pass upwards at rates varying from 2·37 pounds to ·9 pounds per sq. ft. per day. If water rose through soils at even the lesser of these rates, no such thing as a drought could occur, for only the heaviest crops require such a quantity of water as this. Indeed, only one writer on this subject, namely, Mr. Lyman Briggs of the U. S. Department of Agriculture, has suggested a rational explanation of the process involved. A quotation may be here suitably given from his paper (Bull. 10, U. S. Dept. of Agriculture, Division of Soils).

"The limit of the capacity of any soil for water is reached when the surface tension holding the water in the capillary spaces is no longer able to overcome the force of gravity acting on the mass. The relative water capacity of two soils, therefore, depends principally upon the number and size of the capillary spaces. By a capillary space as used here is meant not any interstitial space in the soil structure but only that portion of it which is near the point of contact of two soil grains. It is that portion in which the bounding walls are close together, separated only by distances of capillary magnitude and consequently most efficient in retaining water. It is evident that in a soil of fine texture the grains might be so close together as to make all the interstitial space capillary in its nature.

"The one important factor which determines the acquirement and retention of soil moisture is the curvature of the capillary water surfaces. If equal volumes of two soils are placed in contact, and the curvature of the surface is less in the first than in the second, then water will move from the first to the second, increasing the curvature in one and decreasing it in the other until it becomes the same in both soils. If the second soil contains a greater number of capillary spaces than the first, it will contain more water when equilibrium is established. During the adjustment water will have actually moved from a soil containing a low percentage of water to one having a higher percentage. In

no case, however, will water leave a capillary space having a water surface of large curvature to go to a space with a surface of less curvature. It is the form of the surface which determines the movement of the water."

Thus every soil is able to retain by surface tension a maximum amount of water. Suppose a series of bodies A, B, C, D (fig. 1) placed one upon another in a vertical column and holding a liquid, say water, in the manner suggested by Briggs. It is clear that such water is held by surface tension; it follows then that this quantity of liquid may be held in a column of indefinite length. If, for example, water is allowed to drop on the topmost solid, it will drain away downwards, leaving behind between the solids precisely that quantity of water which the tension of the liquid surface is capable of suspending. The actual shapes of the water films in the soil are naturally less simple than Briggs's illustration, but the latter supplies nevertheless the simplest representation of the case and forms the basis of a correct knowledge regarding the movements of soil water. Applying these principles to the soil, the following deductions may be made :—(*a*) it is clear that the quantity of water present *after drainage has ceased* depends, *inter alia*, on the nature of the soil and not on the depth at which the subsoil water lies; also that if a coarse soil and a fine soil are in contact, the quantity of water in the coarse soil should be less than in the fine soil. (*b*) At the commencement of a dry period, water will assume the gaseous state at the surface of the land; the curvature of the water films in that immediate neighbourhood will be thereby increased and water will commence to flow from neighbouring particles, which in this case are below the surface. The curvature of the water surface

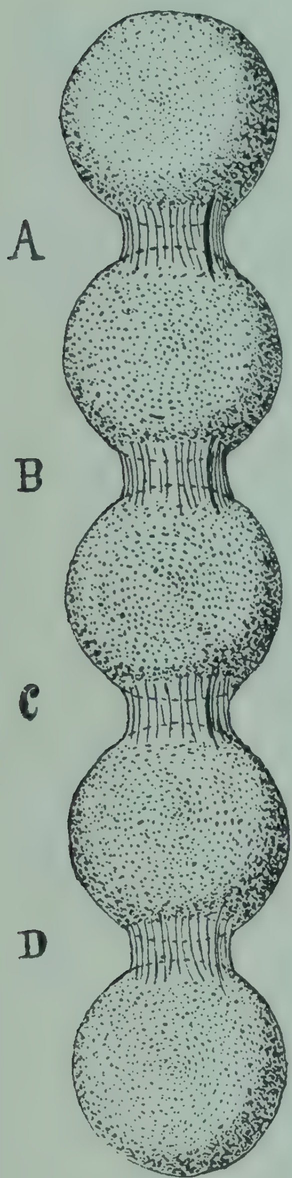

Fig. 1.

is there increased in a similar manner, and water will flow from the next lower lieing, and so on throughout a series. But this process is not an instantaneous one; time is required for water to move from B to A and until the process is established at B, it will not have begun at C; similarly it will only commence at D *after* it is established at C and so on. This principle must apply to succeeding strata of soil as well as to two succeeding particles, and consequently it is not the case that during dry weather water is moving upward towards the surface from *all* depths down to the underground water-level; on the contrary, we may reasonably expect that there is at any time a certain depth from which water has not yet had time to commence to move upward. It is also to be recognised that so soon as this process is established in any stratum, the amount of water per unit volume must decrease. (*c*) If this deduction is proved to be the case, it must follow that provided the soil is *physically uniform*, during dry weather there will be found, commencing from the surface, increasing quantities of water in succeeding strata. Of this being the actual fact there can be but little doubt, for ordinary field observations illustrate it. It is a fact, however, which cannot be explained by the generally accepted idea of "capillarity." (*d*) A further deduction may also be made, namely, the great probability that the rate at which water leaves the soil during dry periods depends on a law similar to that which governs many processes such as loss of heat from warmer to cooler bodies, or the rate of chemical change, that is, the quantity of water lost per unit of time will depend on the amount of water in the soil. If this were true, it would be a decreasing quantity during any dry period. As I have referred in this introduction to Mr. Briggs's hypothesis, it is perhaps necessary to mention that deductions (*b*), (*c*) and (*d*) are my own. It is hardly necessary to refer to the need there is of a correct understanding of this subject. The movement of water in Indian soils, however important, forms only one of several factors which are involved. We speak for instance of soluble manures being washed away by descending water without any clear idea of the rate at which

such water is moving or the distance to which it will move. Similarly in the case of *usar* land, it is assumed that the salts move upwards and downwards although we have no exact knowledge of the real distances through which the movement takes place.

Experimental.

In order to obtain a correct knowledge of soil-moisture conditions, it is essential to make fairly frequent determinations throughout the whole depth of soil which is involved. It is not sufficient for example to record the amount at a particular depth only.

The only accurate means of ascertaining the proportion of water in the soil which we possess is to weigh the fresh earth, dry it and re-weigh it; the loss is assumed to be water. There are other conditions which must be fulfilled, for if the record during a certain period of time is to be at all complete, (*a*) the removal of one set of specimens must not affect the next; (*b*) the whole series must be obtained from such a limited area, that differences in the physical character of the soil may be as slight as possible in the horizontal direction. An ideal case would be realised if the whole of the data could be obtained from one spot; this is impracticable and it merely remains to approach it as nearly as possible. In order to provide these conditions the following procedure was followed:—a plot of land was marked out, and it was decided to restrict the work to fallow land with a loose surface; some records were kept in grass land at first, but it was found impossible to maintain more than one set of data; specimens of the soil were obtained by means of the boring tool subsequently described, to a depth which at first was five feet, and later extended to nine feet from the surface; the relative position of the several borings was such that the one could not affect its neighbour by more than a nominal amount. Regarding this latter point, it will be seen from the description of the boring tool, that after a series of specimens has been removed, an empty

vertical cylinder remains. It is practically necessary to fill this with earth, otherwise the loss of water from this hole might seriously affect the amount of water in the neighbouring soil to an undefined extent; it is also simplest to fill such a hole with dry soil. Now the immediate result of this would be to withdraw moisture from the soil all round. It was assumed that this would take place, and that this dry soil would become equally moist with the surrounding soil, resulting in a lowering of the moisture for a certain distance around its circumference. It was decided that the next boring should not be taken so near that the effect of this partial drying would be as great as ·1 per cent. It was also assumed that the soil contained less than 25 per cent. water, and hence the moisture in the soil surrounding a bore-hole must not be lowered by more than $\frac{1}{250}$th part. It is clear, therefore, that there must be left a volume of soil all round the freshly filled bore-hole 250 times its own volume, or since the hole is cylindrical, the radius of the "*affected*" soil will be to that of the bore-hole as the square roots of the respective cross sections; the radius of the bore-hole was 1″ and consequently that of the "affected" earth would be $\sqrt{250} = 15{\cdot}8''$. Since further the next hole would be ultimately surrounded by a similar column of "affected" soil, the distance between any two holes must not be less than $15{\cdot}8 \times 2 = 31{\cdot}6''$. In these experiments 2′ 9″ was allowed. The plot of land was marked by four pegs at the corners, and a chart prepared; any desired point in the area could, therefore, be readily found.

The boring tool.—This is illustrated in figs. Nos. 2 and 3 and consists essentially of two parts, namely, the handle and the cylinder. The handle is made in sections so as to admit of deep as well as shallow borings. The cylinders are of iron; they are truly cylindrical *inside* and slightly conical in the lower part outside. It may be mentioned that such a tool could not be used in stony land; but the Indo-Gangetic alluvium consists of fine material only, so that with comparatively slight pressure these cylinders can be forced into the soil, and on withdrawal they remain full of undisturbed soil. Any compression to which the soil is subjected

when the cylinder is forced down is suffered by the soil *outside* the borer. On withdrawal the cylinder is detached from the handle, weighed with the soil in it, and the soil then emptied into a weighed tray in which it is dried. It will be evident that this appliance enables one to obtain the proportion of water in the soil with a minimum of error.

Two sizes of cylinder have been employed; namely, one 3″ long for the upper strata where the variations of water are naturally considerable, and one 6″ long for lower strata. Marks on the shaft indicate when the tool had been driven into approximately the desired depth, but a measurement in the hole was also made, because it not infrequently happens that the specimens taken measure somewhat less or slightly more than the nominal 3″ or 6″ respectively. The record of the exact length of the specimens has enabled me to reduce the weight of water found to terms per unit volume, a figure which is of more service than the percentage.

The nature of the soil.—It has been mentioned that the soil of the alluvium consists of fine material; in fact, excepting for beds of soft concretionary lime-stone, the whole of it passes through a sieve of 2 mm. mesh. The soil at Pusa is unusually fine; in fact, as the elutriations show, nearly the whole of it is less than ·2 mm. in diameter.

Chemically it is characterised by containing about 40 per cent. of chalk. The upper two feet may be described as a loam, the next two feet is much more sandy, and below this it consists of a stiff soil for about 15 feet. The depth to water in a well some 50 yards distant was as follows :—

1906	September, 7th	7′ 5″
	October, 4th	13′ 4″
	October, 15th	14′ 5″
	October, 31st	16′ 0″
	November, 19th	17′ 3″
	December, 1st	17′ 8½″
	December, 15th	18′ 1″
1907	January, 3rd	18′ 7″
	January, 15th	18′ 8″

1907	January, 31st	19′ 10″
	February, 16th	20′ 2″
	February, 28th	20′ 4″
	March, 15th	20′ 6″
	April, 1st	20′ 8″
	April, 15th	20′ 10″
	May, 1st	20′ 10″
	May, 18th	21′ 1″
	June, 1st	21′ 8″
	June, 15th	22′ 1″

The great variation in the amount of water at different depths.—The first borings were made early in 1906, and those of 12th February are reproduced in the margin.

Depth.	Water per cent.
0″—3″	16·26
3″—6″	16·05
6″—9″	18·51
9″—10″	21·17
10″—13″	22·91
1′ 3″—1′ 6″	20·79
1′ 6″—1′ 9″	17·89
1′ 9″—2′ 0″	15·78
2′ 0″—2′ 3″	12·50
2′ 3″—2′ 6″	11·80
2′ 6″—2′ 9″	12·67
2′ 9″—3′ 0″	16·19
3′ 0″—3′ 6″	24·11
3′ 6″—4′ 0″	18·12
4′ 0″—4′ 6″	24·19
4′ 6″—5′ 0″	25·37

It is seen that whilst there was 22 per cent. of water at one foot below the surface, there was a sharp decline below this and at 2′ 6″ the soil contained only 11·8 per cent. ; an increase in soil moisture followed this until at 3′ 6″ there was 24 per cent. ; in the next 6″ there was a decline to 18 per cent. followed by an increase. Such differences could not be ascribed to error of experiment ; the three-inch borings weigh between 250 and 275 grms., and as the weight was determined to ·1 grm., no serious error can occur in the weighings. Again, the loss of moisture from the soil between the time it is withdrawn from the hole until it is weighed, does not amount to ·1 grm., and there need be no mechanical loss. Moreover, at the time these specimens were taken there had also been no rain for six weeks. Such differences could only be referred to one cause, namely, difference in the physical state of the soil. This is no new suggestion because the practical agriculturist considers that different classes of soil will hold different amounts of water, though he cannot express the difference more exactly. Mr. Briggs's hypothesis provides an explanation, and he has instanced the effect of physical character in his article in the Year Book of Agriculture, U. S. Department, 1898, page 403. But if this is a correct interpretation, it becomes of all the more importance

to *determine* the exact relationship between physical character of soil and quantity of water held, for if this could be established, it would be possible to determine in the laboratory the amount of water which a soil would hold. The importance of such a method can hardly be overestimated.

At the present time we have only one means of estimating difference of physical character, namely, elutriation, and it was decided to test whether, by this agency, the marked differences in the water capacity of the Pusa soil could be accounted for. This has not been altogether realised; a certain relationship has been established, but it is not of a simple character, and since an examination of the moisture data, apart from the exact physical state of the soil, lead to some interesting results, these will be considered first, and the relationship between physical character and amount of water in a later paragraph.

The data which I propose to consider particularly, relate to the period September 1906 to June 1907, *i.e.*, the dry weather period. The details are set out as follows :—Statement I, percentage of water (dry soil = 100) ; Statement II, grms. of water per c.c. of undisturbed soil ; Statement III, lbs. of water per c. ft. also of undisturbed soil ; Statement IV, lbs. of water present in the part of each c. ft. examined, that is, if the boring were 3 in. long, this is reckoned as $\frac{1}{4}$ c. ft. ; if 6 in. long, $\frac{1}{2}$ c. ft.; in other words, these figures represent the pounds of water in each section of a vertical column of soil, the cross section of which is 1 sq. ft. The statements III and IV will be the most useful. At first the borings were carried to only 5 ft. deep, but it was soon observed that the dry period was affecting the soil to fully this depth, and since it was most desirable to ascertain the water content to a greater depth than that which was affected by the dry weather, an extra long handle was obtained, and the borings carried to 8 and 9 ft. from the surface. Until the borings were carried below 5 ft., the amount of water was determined in every boring, but when the record was extended to 8 and 9 ft., this became impracticable ; the water was then only determined in alternate borings below 12 in. and

the probable amounts in the remaining strata were determined by interpolation. This has been done in statement IV only, and these deduced figures are printed in brackets.

Previous weather conditions.—A description of the rainfall previous to the commencement of the moisture data is desirable.

The monsoon of 1906 was late, and drainage only commenced to flow freely from the six-feet gauge[1] about the middle of July; the major part of the rainfall occurred in August when 24·8 inches fell; September was comparatively dry. The precise details of rainfall are set out in statement V.

STATEMENT V.

Rainfall previous to commencement of observations.

June 1906.		July 1906.		August 1906.		September 1906.	
1st—7th ...	·30	1st—7th ...	1·04	1st—7th ...	7·08	5th ...	·01
8th—15th ...	...	8th—15th ...	7·76	8th—15th ...	11·64	8th ...	·40
16th—22nd ...	1·11	16th—22nd ...	·55	16th—22nd ...	2·98	9th ...	·72
23rd—30th ...	4·07	23rd—31st ...	2·20	23rd—31st ...	3·11	10th ...	·37
......	...	......	...	......	...	12th ...	·64
......	...	......	...	......	...	13th ...	·24
......	...	......	...	......	...	14th ...	·08
......	...	......	...	......	...	15th ...	·22
......	...	......	...	......	...	18th ...	·13

Rainfall during period of observation.

I period.		IV period.		V period.	
26th Sept. ...	·22″	5th Feby. ...	·12″	20th Feby. ...	·08″
28th ,, ...	·03″	6th ,, ...	·30″	4th March ...	·01″
1st Octr. ...	·32″	7th ,, ...	·71″	11th ,, ...	·20″
7th ,, ...	·16″	13th ,, ...	·01″	12th ,, ...	·42″
8th ,, ...	·08″		1·14	16th ,, ...	·11″
19th ,, ...	·01″			17th ,, ...	·12″
	·82			18th ,, ...	·78″
				22nd ,, ...	·11″
				23rd ,, ...	·02″
					1·85

[1] There are four gauges at Pusa for determining drainage conditions, a description of which is given in Memoir No. 5.—J. W. L.

Rainfall during period of observation—concld.

VI period.			VII period.	
10th April	... ...	·36″	19th May ..	·33″
16th „	... ...	·01″	1st June ...	1·75″
18th „	... ...	·46″		
29th „	.. ..	·03″		
30th „	... ...	·03″		
		89·		

It is perhaps necessary to mention for those who do not know India, that the Indo-Gangetic alluvium consists entirely of beds of loams, sands, clays, succeeding one another in a more or less well-defined manner. Now, it is a mistake to suppose that because water is found in a certain sandy stratum, no water is draining through the clay below. Clays are not impervious to water; they are merely relatively so. On the other hand, water may accumulate in a sandy stratum much more quickly than it can pass through the underlying clay, and consequently in such a case "underground" water will be found in the sand. Given, however, sufficient time, the excess water will pass through the clay and the sand will not yield water. An upper sand stratum may therefore during periods of excessively wet weather hold the first "underground" water. Owing to the heavy rain during August this occurred in the Pusa soil last year; the underground water was temporarily at four feet from the surface. It was only a temporary state, and drainage ceased from the six-feet gauge from September 6th.

Let us compare also the quantity of water present on July 19th, August 23rd and September 19th. It is clear that the soil was not fully saturated on the former date, that in the middle of August there was excess of water below 3 ft.; thirdly, that by the middle of September the soil contained as nearly as possible as much water as it could hold by surface tension as defined by Briggs's hypothesis. Moreover, there was light rain most days prior to September 19th, and it is probable that at the latter date the soil was just about fully saturated in the surface soil. When the first specimens were taken, the whole

column of soil contained just about as much water as it would hold by surface tension, while it had not had time to dry materially in the surface layer.

The decrease in the quantity of water.—It will be most convenient if we confine our attention to statement III where the pounds of water per c. ft. in the different strata are set out. It will be seen that the dry weather succeeding September rapidly influenced the water in the soil to a depth of 5 ft. ; but this influence is not regular. The decrease in the first foot of soil was appreciable in the first month, namely, about 3lbs., but there was no very marked decrease in the second foot until after March ; in the third foot, *i.e.*, the more sandy soil, the water fell to one-half in two months ; and in the fourth foot the loss was eventually even greater than in the third ; below four feet the decrease, though perceptible, was only slight. Later on there was a loss down to a depth of about 7 ft. It is necessary to digress for a moment. The soil examined from depth x at one point in the experimental plot may not be precisely like that taken from the same depth at another point, although only a few feet may separate the two. Consequently differences between individual specimens at this or any particular depth must be substantiated by the quantities found previously and subsequently at the same depth. For example, in May the fourth foot was found to contain only six pounds of water which is much less than the soil of the third or fifth foot, but the correctness of the figure is substantiated, firstly, because it is evident from previous borings that this soil was losing water very rapidly, and, secondly, by the subsequent sample in June. In order then to obtain a correct estimate of the rate of loss, the data should be considered broadly.

Accordingly the quantities of water found in each succeeding foot of soil are set out in statement VI. From this it is evident that the loss from the third foot was most rapid and next to it the fourth foot ; from the stiff soil below this, the loss was much less, and in the seventh foot it was nominal. The rapid loss of water from the third and fourth feet is very striking ; and for some time I attributed it to belated drainage. But if drainage

had been in progress, the soil below 4 ft. could not at the same time have lost water, whereas it did so; the loss in the fifth foot was only small, but it was definite and the same must be said of the sixth foot. It forms a good illustration of the truth of

Statement VI.

	19th Sept.	20th Oct	30th Nov.	8th Jany.	15th Feb.	27th Mar.	6th May.	5th June.	15th June.
				lbs. of water.					
0—1 foot ...	18·97	15·78	14·21	12·15	12·10	14·18	10·83	13·87	10·41
1—2 feet ...	·96	19·27	17·95	18·17	18·79	19·62	16·39	15·40	15·38
2—3 "	24·75	18·84	10·68	11·95	12·00	10·51	10·35	9·67	9·03
3—4 " ...	25·95	17·51	18·35	13·54	11·27	9·27	6·55	6·63	6·36
4—5 " ...	25·65	23·69	21·91	21·07	20·18	19·56	18·10	16·20	16·64
5—6 " ...	26·42	25·60	24·50	24·00	23·54	22·45	20·82	19·45	18·99
6—7 " ...	26·42	26·00	25·00	25·00	25·30	25·26	24·5	23·10	24·00
Total ...	169·12	146·69	133·00	125·88	123·18	120·85	107·57	104·32	100·81

Briggs's hypothesis. The sandy stratum contained relatively more water than the loam above, and surface tension occasioned a movement of this excess water into the loam in the second foot at a rate nearly coincident with that at which the second foot

delivered water to the soil in the first foot. This is best illustrated by comparing the rates of loss from these strata.

	Loss. 3rd & 4th feet.	Loss. 2nd foot.
1st period	14·4	14·4 + 1·7
2nd period	7·3	7·3 + 1·3

That is, the second foot lost about one pound more water during the first and second periods than it received.

One conclusion may be definitely drawn from these data, namely, that the deduction made under (b) (page 81) is correct, for it is evident that throughout the nine months of practically dry weather no water moved upwards from a greater depth than 7 ft. ; below this the water was stationary.

The total loss of water.—In order to form an estimate of the total loss of water during the period, the quantities of water present in the upper seven feet must be considered. As no borings lower than 5 ft. were taken until February, it is necessary to assume probable quantities in the sixth and seventh feet up to February, and similarly, as has been fully explained, the amount of water in some of the alternate borings since February has had to be obtained by interpolation. The total water found in each set of borings is placed in the last line of statement No. VI, and it will be seen that, commencing with 169 pounds in the whole seven feet in September, there remained 101 pounds on June 15th; 68 pounds had therefore evaporated, in addition to the 35 pounds of rain per sq. ft. which fell during the period. The 68 pounds is equivalent to about 40 % of what was in the soil in September at the conclusion of the monsoon, and is rather more than was contained in the uppermost 3 ft. at that time.

The distance to which water moves upwards.—Some writers make a wrong deduction regarding the height to which the water rises during dry periods. For example, King (Experiment Station Record, Vol. XII, page 35) discusses the data of some experiments in which soil, 10 ft. deep, was exposed to drying influences for 10 days, at the conclusion of which time the loss of water

appeared to be felt slightly at 10 ft. from the surface, and he says: "It is certain that a drying of these soils had taken place through a depth of 10 ft. and hence the moisture 10 ft. below the surface of the ground may become available for vegetation purposes at or near the surface." And Hall (Journal of Agricultural Science, Vol. I, p. 245) expresses the opinion that nitrates could come from the underground well water at Rothamsted, a distance of some 20 ft. during such brief dry periods as Hertfordshire enjoys, and which are rarely so long as one month. Because water moves *towards* the surface during a dry period is obviously not a proof that it *reaches* the surface. Taking the Pusa data of the past year into consideration, it may be said that the water which was at about 3′ 2″ below the surface in September, reached the surface during the dry weather and evaporated; that the water which in May was in the upper three feet, had come from the fourth and fifth feet; the water which left the seventh foot was only some 3 pounds and merely moved into the sixth foot. It is of course impossible to say from the data we are considering what would happen in other soils. For example, supposing the stratum of sandy soil had been 10 ft. instead of 2 ft. thick, the presumption is that more water would have been lost, partial drying to a greater depth would have been experienced and the water would have moved probably further in the given time. I deduce this merely from the greater rate at which this sandy soil lost water than the loam above it. But it must be rare indeed that water, which at the conclusion of the Indian monsoon is in the *underground water stratum*, reaches the surface during the dry weather period. Similarly, it is equally improbable that the dissolved substances in such water, whether they are the valuable nitrates or the obnoxious *usar* salts, can reach the surface.

The rate at which water was lost.—The third deduction which I made (page 82 (d)) from Briggs's hypothesis is that the quantity of water lost per unit of time will depend on the amount of water in the soil, that is, as the quantity in the soil decreases, so will the rate of loss decline. This is not so simple

a case as loss of heat, or amount of chemical change, both of which follow this law, for it is complicated by the variation in physical nature of the soil and by the ever-increasing depth of soil which becomes involved. Broadly speaking, the data support the hypothesis. The losses from the whole seven feet were as follows :—1st period of 31 days, 22·4 pounds or ·72 lbs. per day; second period of 41 days, 13·7 pounds or ·33 lbs. per day; third period of 40 days, 7·1 pounds or ·18 lbs. per day. The law would be expressed mathematically $\frac{1}{t_n - t_o} \log \frac{Q_o}{Q_n} = \text{constant}$, where t_o is the commencement of the time, t_n the time in days, Q_o the quantity of water present at the commencement and Q_n the quantity present at t_n. But there are other factors which must affect the rate of loss. Temperature and humidity of the atmosphere are two.

Temperature affects both the surface tension and the viscosity. The effect of a rise of temperature on *surface tension* is to lower it, and since this is the cause of water moving upwards in the soil, any decrease in its value would cause a decreased rate of flow towards the surface. This effect would naturally apply to other directions also, but we are only concerned at present with the upward movement. Unfortunately it has not been possible in the past season to maintain a record of soil temperature, and for the purpose of calculation the mean temperature of the air has been assumed to coincide more or less with that of the soil. This has varied from 18° C to 32° C. The surface tension at 18° C = 72·8 dynes per cm., at 32° C = 70·7 dynes. The effect therefore of this change of temperature is only nominal throughout the whole period. The effect of a rise of temperature on the *viscosity* of water is to *decrease* it, with the result that any given force (in this case surface tension) would move a greater quantity of water in unit time. The effect on viscosity is much greater than on surface tension. Taking again the extreme temperature involved, the viscosity at 18° C = ·0105 dynes, at 32° C it is ·0077 dynes per sq. cm. Thus, assuming the viscosity of the soil water to be approximately equal to that of

water, about 1/3 more would flow in unit time at the higher than the lower temperature.

The *humidity* of the atmosphere must also be expected to affect the rate of evaporation. If the atmosphere is saturated, it is clear that no evaporation can take place, and similarly, if the humidity is high, the rate of loss must be lower than if the air is dry.

Broadly speaking, these factors would tend to reduce the rate of loss of water from the soil very much during the cold weather, whilst conversely during the hot and dry weather the rate of loss would be much increased.

It follows from these considerations that the velocity of flow, V, would vary directly as the surface tension τ and indirectly as the viscosity, η ; it would also vary indirectly as the relative humidity of the atmosphere H.

$$\text{Thus } \frac{V'}{V''} = \frac{\tau'}{\tau''} \times \frac{\eta''}{\eta'} \times \frac{H''}{H'}$$

$$V'' = V' \times \frac{\tau''}{\tau'} \times \frac{\eta'}{\eta''} \times \frac{H'}{H''} \text{ or } V' K' \text{ (say).}$$

If the general assumption, that the rate of loss depends on the compound interest law, holds good, then

$$V = \frac{dx}{dt} = K(a-x)$$

which on integration yields

$$\log a - \log (a-x) = K t$$

or after introducing the correction for temperature and humidity

$$\log (a-x) = \log a - K K' t,$$

K is a constant obtained for the whole period at mean temperature and humidity (= ·00154). Since the effect of temperature variation on τ was slight and it was known that this formula is not perfect, the surface tension has been assumed to have been constant throughout. In addition to the allowance for the effect of humidity which is included in the formula, I have felt it necessary to assume that while heavy dews occurred, the " day " must be taken at only 12 hours so far as evaporation from the soil is

concerned. A record of the dew was kept throughout the cold weather. The deposit was very regular; it commenced to be heavy on October 14th and continued until the end of February. Every night throughout this period the deposit commenced about 5 or 6 P.M., and evaporation recommenced about 6 A.M. It seems reasonable to assume that evaporation was suspended at night for this period. The result of the computation is set out in the chart, fig. 4.

The quantities of water actually found in the 7 ft. of soil and those calculated are set out in statement VII; the rain which occurred during each period is noted, though it is not included in the water lost.

Statement VII.

	Found lbs.	Calculated lbs.	Found lbs.	Calculated lbs.
	Total.		Loss.	
September 19th, 1906	169·1	...	...	...
October 20th, 1906	146·7	(4·2 lbs. rain per sq. ft.) 155·9	22·4	13·2
November 30th, 1906	133·0	(no rain) 145·4	13·7	10·5
January 8th, 1907	125·9	(no rain) 137·6	7·1	7·8
February 15th, 1907	123·2	(6·0 lb. rain per sq. ft.) 135·1	2·7	2·5
March 27th, 1907	120·8	(9·6 lbs. of rain) 128·6	2·4	6·5
May 6th, 1907	104·3	(4·6 lbs. of rain) 103·8	3·3	4·5
June 15th, 1907	100·8	(no rain) 99·1	2·5	4·7

An examination of the chart and of this statement shows that the calculated *rate of loss* was in considerable defect during the first period (September 9th to October 20th); it then agrees closely with the actual until the hot weather March to May when it was greater than the actual, after which agreement again occurs.

The effect of rainfall.—The effect of such rainfall as occurred is best traced in statement IV. Although borings were not made immediately subsequent to rain, it is clear that in no case was the moisture increased beyond about 1′ 6″ from the surface. The rainfall of February 5th, 6th and 7th, 1·13″, seems to have

affected the first foot; that of March, 1·77″, appears to have increased the moisture in the second foot; that of June 1st, 1·75″, affected only the first foot, or at least this is all the evidence of increased moisture remaining on the dates of sampling.

Relation between physical state and amount of water.—The term "Physical state" is often employed in regard to soils as though it were an entity. That it is a mistake to use it in this sense will be readily admitted. The physical properties of soils are, doubtless, as numerous as their chemical properties. It is probable that the collective term is employed because of our general ignorance of the precise properties which occasion or control certain effects. The quantity of water held by soils is one of these effects.

In an earlier paragraph I have sufficiently explained my reasons for considering Mr. Briggs's hypothesis a reliable one. According to it, the water in the soil should distribute itself by surface tension among the particles in such a manner that when the soil is losing water neither by drainage nor evaporation, the curvature of the small surfaces will be equal. Under such circumstances, the amount of water held between any two large particles will be greater than between any two small ones, but the quantity of water held by a unit volume of small particles will be greater than by the unit volume of large particles. In short, a sandy soil should contain a less amount of water than a finer soil. Such is the hypothesis. I have also pointed out that the earliest borings in the Pusa soil showed considerable differences in the amounts of water contained in the 100 parts of soil (by weight), the differences being indeed more marked than an inspection of the soil would have led one to anticipate. Although it is simple to refer such differences to difference of "physical properties", such a conclusion is of no practical utility. If the effect is due to that cause, it becomes essential to the correct solution of the problem that the real nature of the particular "physical properties" shall be established.

One suggestion very naturally occurred, namely, to compare the total surface possessed by the soil particles with the water

present. This physical property, although difficult to estimate correctly, is at least fairly well defined.

Mr. Briggs's hypothesis does not demand that the quantity of water present shall correspond to the *total surface*; it would demand a *relatively* smaller amount of water per unit of surface in coarse than in fine soils. But since any one soil does not consist simply of particles of one size, there being merely a larger proportion of coarse, or of fine particles in its volume, one cannot expect that this feature will be in any case well marked.

On noticing the varying proportions of water in the Pusa soil, I decided to employ the only means we have for the determination of the total surface of the soil particles, namely, elutriation, and make the indicated comparison. The result of one of the first experiments was extremely encouraging and is shown in the marginal statement VIII. As already seen, the experiment supported the hypothesis, and a close relationship between water and total surface was demonstrated. This work was, therefore, prosecuted. Other features also came into evidence and will be referred to subsequently.

STATEMENT VIII.

Depth.	Water. %	Ratio water : surface.
9″–1′ 0″	20·91	·073
1′ 0″–1′ 3″	23·00	·074
1′ 3″–1′ 6″	19·84	·071
1′ 6″–1′ 9″	16·30	·068
1′ 9″–2′ 0″	12·57	·081
2′ 0″–2′ 3″	9·87	·080

Method for the determination of the total surface.—Only one method for the approximate estimation of the total surface is available, namely, the separation of the several principal grades of particles by sedimentation or elutriation, and the ascertainment of their magnitude. Of elutriation methods I have found simple sedimentation in beakers very good. Without criticising other methods specifically, it may be said that for the grading of the *finest* portions, I have found the beaker method preferable to any "running water" method.

The process which I have employed is extremely simple. A weighed portion, usually 10 grms., of the air-dry soil is heated with water and then stirred up in cold water, 10 cm. deep, in a

beaker; subsidence is then allowed for a definite period, the muddy water decanted and the process repeated so long as is necessary. The mean diameter possessed by the particles is then obtained by a microscopical estimate, and the total surface deduced from this on the assumption that the particles are spheres, together with the ultimate dry weight of the sediment. The periods of sedimentation employed have been 24 hours, 30 minutes, 10 minutes, 75 seconds. In some of the work a 6 hours' sedimentation was used and will be specially noticed. It was without material influence on the result.

There are one or two points that are here deserving of special remark.

(*a*) The *uniformity* of the sediments is naturally most important, and in this respect I have found the method more reliable than might perhaps be anticipated. In Figs. Nos. 5 to 8 are reproduced the photomicrographs of a series of sediments together with the magnification, and it is apparent that from such sediments it is quite possible to estimate the mean diameters. They have been all through the work most reliable. The only sediment which, microscopically, has proved irregular, is that for 24 hours. It is commonly called "clay", and consists for the most part of ill-defined material together with a small quantity of particles of irregular size. The Pusa soil contains very little of this, so much as 3 per cent. being very unusual.

(*b*) The sub-division of the two hours' sediment into two portions, one of 6 hours' sedimentation and the other of two hours, was tried in a number of specimens, but the effect of making this differentiation was only slight. For example :—

STATEMENT IX.

Depth.	With 6 hours' sedimentation followed by 2 hours' sedimentation $R \times 10^{8}$.	With only 2 hours' sedimentation. $R \times 10^{8}$.
2′ 9″—3′ 0″	......	7·6
3′ 0″—3′ 6″	8·0	......
3′ 6″—4′ 0″	.. ...	6·8

Depth.	With 6 hours' sedimentation followed by 2 hours' sedimentation. $R \times 10^5$.	With only 2 hours' sedimentation. $R \times 10^5$.
4′ 6″—5′ 0″	9·3	......
5′ 6″—6′ 0″	......	8·7
6′ 6″—7′ 0″	6·6	.....
7′ 6″—8′ 0″	......	7·6
8′ 6″—9′ 0″	7·6	......

(*c*) The effect of employing dilute ammonia instead of water for the sedimentations has been recommended by some ; it was only used in a few tests, but this also yielded results which agreed well with what had been obtained by means of pure water. The figures are sub-joined.

	(1)	(2)	(3)	(4)
		Sq. cm. per 1 c. c. of soil.		
With water only ...	1823	1578	1947	3876
With dilute ammonia ...	2128	1787	2113	3356

(*d*) It is desirable to decide in some methodical way, how often to decant the suspended sediment. It is commonly recommended that sedimentation should be repeated until there remains no suspended matter at the conclusion of the stated period. In my experience this point is either never reached or it is reached only after the employment of altogether excessive amounts of water. In attempting to arrive at a really clear supernatant liquid I have frequently had to use so much water that the quantity of soil dissolved would be greater than the suspended matter. Indeed, there is no object in carrying out the separation of the sediments in this way. Suppose, for example, elutriation is stopped for any particular sediment when only 9/10 has been separated, and the remaining 1/10 is left to be separated with the next coarser material, what will be the ultimate effect on the estimate of surface ? Here is a comparison :—

(i) $R \times 10^5 = 7{\cdot}0$; if 1/10 of each sediment had been left as suggested, the ratio becomes 7·5.

(ii) $R \times 10^5 = 11{\cdot}0$; if 1/10 of each sediment had been left over, it would have become 11·8.

Such differences, though appreciable, are not so great as the other errors of experiment which are necessarily involved. At the same time there is no necessity to leave even so large a proportion of any sediment as 1/10. If the series of decantations are poured into separate vessels, it is seen that the quantity of sediment in each succeeding decantation diminishes rapidly, and in fact it will rarely or never be found that the amount of sediment in the tenth decantation forms a material proportion of the whole. The following procedure has, therefore, been adopted in this laboratory ; the first three decantations are poured into one vessel, and the succeeding three into another ; it is quite easy to judge by the eye whether the latter is much less than the former or not: if it is large, then decantation is continued for another three times. It often happens that the amount of sediment obtained in the second three decantations is so small that the whole of that particular grade may be considered to have been satisfactorily separated, and further sedimentation becomes unnecessary. As an example of the reliability of this mode of procedure, the following may be quoted :—

By decanting until the water was clear.	By decanting 6 to 9 times according as considered desirable.
Sq. cm.	Sq. cm.
3097	3138

After completing the elutriations the surface possessed by the various sediments was calculated as sq. cms. and from this was deduced the surface per 1 c. c. of soil *in situ*. This is called S. The ratio of water (1 c. c. = 1 grm.) per 1 c. c. of soil to S was then obtained. It is called R. As it is a small fraction, it is convenient to multiply it by 10^5.

The whole of the samples from September 1906 to May 1907, besides two series in March and April 1906, 157 in the aggregate. have been thus tested and the details are set out in the Statements Nos. X to XIX. For the purpose of more easy reference the values of $R \times 10^5$ are collected in Statement No. XX which

Statement No. XX.

Values of $R \times 10^5$.

Depth.	1906. 19th Mar.	2nd April.	19th July.	19th Sept.	20th Oct.	30th Nov.	1907. 8th Jany.	15th Feb.	27th Mar.	6th May.
0″	11·4	8·91	10·90	15·86	10·6	10·4	8·7	9·8	8·6	6·1
...	8·64	8·95	10·34	11·75	9·28	8·9	7·4	8·8	8·4	6·9
...	7·75	6·54	8·54	9·13	7·21	7·7	8·1	7·5	6·8	6·1
1′ 0″	7·73	7·24	8·65	8·60	7·26	6·9	8·4	7·8	5·8	5·6
1′ 0″	7·06	7·33	8·05	8·56	7·66	6·5	7·0	...	...	...
...	7·38	7·14	8·02	8·99	7·99	7·0	7·7	5·6	5·6	5·9
...	7·95	6·77	8·73	9·76	8·79	8.0	7·7	...	...	...
2′ 0″	8·94	8·16	12·60	10·90	10·3	9·5	8·5	7·2	7·4	7·0
2′ 0″	9·66	8·04	16·89	17·39	13·7	10·6	8·9	...	...	...
...	10·10	10·17	19·26	18·19	15·2	11·2	10·2	9·5	11·6	7·9
...	10·50	11·16	22·22	18·17	16·9	11·0	...	...	...	...
3′ 0″	10·25	10·96	19·84	22·16	20·4	11·9	11·1	10·8	10·3	7·6
3′ 0″	...	...	...	...	...	...	...	...	...	...
...	11·08	11·71	20·14	39·84	17·0	13·9	12·4	15·5	11·3	7·9
...	10·12	10·84	10·77	14·41	17·2	13·5	11·6	...	8·3	6·9
4′ 0″	...	...	...	...	...	...	...	...	...	...
4′ 0″	...	...	...	...	...	...	...	...	...	...
...	10·43	9·67	11·42	11·65	11·3	9·7	9·8	8·7	...	...
...	11·77	11·58	14·47	17·90	13·6	12·8	11·6	10·1	10·0	9·3
5′ 0″	...	...	...	...	...	...	...	...	...	...
5′ 0″	...	...	...	...	...	...	...	...	...	...
6′ 0″	...	...	...	...	...	...	...	9·3	7·2	8·7
6′ 0″	...	...	...	...	...	...	...	...	...	...
7′ 0″	...	...	...	...	...	...	...	7·1	7·9	6·6
7′ 0″	...	...	...	...	...	...	...	...	...	...
8′ 0″	...	...	...	...	...	...	...	7·7	7·1	7·5
8′ 0″	...	...	...	...	...	...	...	...	...	...
9′ 0″	...	...	...	...	...	...	...	...	7·9	7·6

exhibits the nett results very well. In the first place, the ratio for the borings of September 19th should be compared with the water per c.ft. (Statement III). From the latter it is seen that the amount of water rose from about 16lbs. per c.ft. in the second three inches to about 25lbs. at 2′ 6″, after which the variations were nominal. This was at a period immediately after drainage had ceased. It was reasonable to anticipate that the sandy stratum would have a relative excess of water; in other words, R should be higher in the sandy stratum at that time than either in the loam above or in the clay below. Reference to Statement No. XX shows that in fact this was the case. R is very fairly constant until the sandy stratum is reached; in this it is high, being exceptionally high at 3′ 0″—3′ 6″ below which it rapidly declines again. So far then the actual state agreed with anticipation. In the next place, it was to be expected that there would follow a redistribution of water from the sandy stratum to the loam and the clay so that R would become uniform. This also occurred, although the change was more gradual than I expected, and the great difference in this ratio of September took about ten weeks—until the end of November—to disappear. The alteration of these ratios coincided with the losses of water by evaporation. It may be suggested that the upper loam contained its maximum amount of water, and that if water was brought into it from below, a like quantity must pass upwards away from it; that is, R could not be greater in this soil, *i.e.*, the upper loam, than about 9×10^{-5}. It is also to be noted that R could be more than three times as great in the sandy soil as it ever was found to be in the loam or the clay, excepting when drainage was in progress in the latter (*vide* 5′ 0″ on September 19th; R = 17·9 indicates that drainage perhaps had not quite ceased at this depth). Another point to be noted is that when this ratio was abnormally high, the rate of evaporation was likewise higher than was expected from the mode of calculation which I have adopted in the former part of this Memoir.

Passing in the second place to a review of R during the later periods, it will be seen that it decreased in all strata, though the

amount of change in its value varied a good deal. In the first foot the change was gradual throughout the season ; fluctuations occurred, but these could be accounted for by individual rainfalls. In the second foot the change was gradual until February after which the ratio became approximately constant. In the third foot the fall in the value of R was very rapid during the first two months, after which it decreased gradually. To the next six inches of soil, the most sandy of all, a similar remark applies. The following six inches of soil varied a good deal among the borings. In the fifth foot the value of R fell regularly throughout the season.

Some of the data of water per c. ft. and the ratio, R, may be collected for comparison and the season divided into two periods, namely, September to November and November to May.

	September to November.		November to May.	
	$R \times 10^5$.	Water per c. ft.	$R \times 10^5$.	Water per c. ft.
0″—1′ 0″ ...	11·3 – 8·5	18·9—14·2	8·5—6·1	14·2—10·8
1′ 0″—1′ 9″ ...	9·1— 7·2	20·7—18·6	7·2—5·9	18·6—18·1
2′ 0″—3′ 0″ ...	19·0—11·2	24·7—10·7	11·2—7·6	10·7—10·4
4′ 0″—5′ 0″ ...	14·8—11·2	25·6—21·9	11·2—9·3	21·9—18·1

An inspection of these figures shows that the change in the value of R followed generally that of the water ; in the first foot and the following nine inches and in the fifth foot this change was indeed as nearly proportional as could be expected ; in the sandy soil of the third foot the relationship was imperfect. Here again, then, irregularity is apparent in the sandy subsoil.

The general value of elutriation.—The question may naturally be considered whether elutriation may be employed to determine the maximum quantity of water a soil will hold and the probable rate at which it will lose water in dry weather. Only approximate deductions can be drawn from the data at hand, which may be thus stated :—

(*a*) The sandy stratum possessed a surface of 1,000 to 2,000 sq. cm. per c.c. of soil. This is the soil which lost its water so rapidly.

(*b*) The loam from 1′ 9″ to 2′ 9″ possessed a surface of 3,000 to 4,000 sq. cm. per 1 c.c., and it retained its water extremely well.

(*c*) The same remark applies to the clay below the sand, though its surface was equal to 3,000 up to 6,000 sq. cm. per 1 c.c. Until, however, a greater variety of soils have been tested, it will be impossible to say whether elutriation will yield with them corresponding results. Obviously, however, if by elutriation the water holding capacity of soils can be determined, it is clear that the method would have a great agricultural value.

General conclusions.—The general conclusions which may be drawn from the data dealt with in this memoir may be summarised as follows :—

(*a*) During a dry period water moves upwards towards the surface from a *limited* depth only ; this limited depth increases with the period. Below this depth the water is stationary, or possibly is still draining downwards. In the Pusa soil this depth was eventually about 7 ft. If the sandy stratum had not been present, it would probably have been much less.

(*b*) In the Pusa soil the maximum distance that water moved upwards was somewhat more than three feet during the whole period, and this distance was considerably less for the water which was originally in the lower strata.

(*c*) Water is lost from the soil at a rate dependent on the amount of water present, *i.e.*, it follows the "compound interest law." It is influenced by temperature because of the marked change of viscosity ; the change in the surface tension is only slight for such ranges of temperature as occur. It varies inversely with the humidity.

(*d*) The rate of loss is much greater immediately after rain than subsequently.

(*e*) The effect of such cold weather and hot weather showers as were experienced during the period under review (maximum 1·75″) increased the water throughout the first foot, but did not extend below the second foot of soil.

(*f*) All soil such as is included in the strata examined will contain about 25lbs. of water per c. ft. at the conclusion of the monsoon, provided this is normal.

(*g*) A soil possessing not more than 2,000 sq. cm. of surface per 1 c.c. of soil *in situ* will lose water very much more rapidly than one possessing 4,000 to 6,000 sq. cm. of surface.

(*h*) There is one case which perhaps specially requires remark, namely, the rate of loss from a very sandy soil. It has been shown how rapid this was from the sandy subsoil at Pusa. But if a sandy soil is exposed *at the surface*, the circumstances are altered in one particular. At first the loss would be rapid, but this class of soil dries so effectively at the surface that several inches will become air-dry. The soil in which surface tension is able to act is therefore protected by a layer of dry material, through which water passes, not in the liquid form by surface tension, but as gas by diffusion. This process is extremely slow. In a recent paper by Mr. E. Buckingham (Bull. 38, U. S. Dept. of Agric., Bureau of Soils) he describes experiments in which the loss by gaseous diffusion through only 2″ of dry sand aggregated only 1·4 to 4·3 inches per 12 months. Consequently after the surface two or three inches of a sandy soil have become *really* dry, the rate of loss would be largely controlled by this factor and would become less. This explains why very sandy soils, although quite dry at the surface, are always found to be perceptibly damp a few inches below.

(*i*) The water-retaining power of a soil after drainage has ceased, is closely related to the total surface possessed by the solid particles, and it is probable that from a determination of the latter, the water-holding capacity of soils may be ascertained.

(*j*) These conclusions have a value beyond the mere knowledge of the rate of movement of water. They show that soluble substances, valuable plant-foods as also deleterious alkali salts, cannot move during dry weather more than a very limited distance. It is impossible, for example, for salts which are present in well-water to reach the surface unless that subsoil water is only at a very moderate depth, such as 5 or 7 ft. This not merely limits

assumptions on the subject of alkali, but also simplifies work in relation to the possible distribution of plant food.

(*k*) These deductions are in accordance with what is known in practice. They explain why a crop will wither when the soil below the root range still contains abundance of water; the latter simply cannot move upward fast enough to meet the plant's requirements. Also, why a crop will mature in some soils with a very limited assistance from rain or irrigation, whereas in other soils the crop will require this aid constantly throughout the period of growth. Broadly speaking, crops depend simply on the water which is present in the stratum in which they are developing and receive only a very limited assistance from below. It is also clear why it is that only the uppermost soil dries to any marked extent.

(*l*) The term "capillary" should be discontinued in relation to soil moisture conditions. It is true that surface tension is the cause of liquids rising in capillary tubes, also the cause of the retention of water in soils; but the term capillary should be restricted to the case of a liquid completely filling a narrow space. In the upper soil, *i.e.*, the aerated soil in which our crops develop, this condition does not obtain and hence the impropriety of the term "capillary."

	1907.					
Nov. 30th $H_2O\%$	Jan. 8th $H_2O\%$	Feb. 15th $H_2O\%$	March 27th $H_2O\%$	May 6th $H_2O\%$	June 5th $H_2O\%$	June 15th $H_2O\%$
No. 13	No. 14	No. 30	No. 35	No. 27	No. 31	No. 36
15·85	12·77	14·48	12·48	8·81	17·13	8·58
16·67	12 49	15·38	13·65	11.04	13·82	13·12
16·35	13·96	15·35	15·42	12·23	14·72	13·49
19·77	19·76	15·95	20·35	18·10	19·06	12·70
22·62	23·25	......	......	......	......	......
22·75	23·09	22·83	23·29	21·01	20·43	19·84
21·42	21·89	......	......	..	......	......
19·36	20·68	22·24	17·22	13·98	13·91	13·80
14·39	17·11	......	......	......	......	......
11·88	12·94	12·05	17·29	11·70	11·84	10·02
12·22	12·58	......	......	......	......	......
15·44	16·54	15·99	14·79	13·24	11·02	11·54
24·61	20·38	15·73	11·42	6·23	6·19	6·74
19·81	12·69	......	...	9·85	10·75	9·13
24·39	22·69	22·66	......	...	......	......
25·46	23·20	22·49	22·48	20·58	18·22	17·67
......	......	26·00	25·13	24·09	21·81	26·50
......	......	28·02	26·75	27·14	24·81	26·50
......	......	28·30	24·21	28·08	26·14	26·59
......	......	......	29 13	28·77	28·57	28·53

6′ 0″—6′ 6″ ..	..	...	...	...	...	..	...	...	·4087	·4147	·4079	·384	·4066
6′ 6″—7′ 0″ ...	...	...	...	...	...	..	...	...					
7′ 0″—7′ 6″ ...	..	...	...	..	...	...	...	...	·4107	·3593	·4212	·405	·4060
7′ 6″—8′ 0″ ...	...	.	..	...	...	..	...	..					
8′ 0″—8′ 6″ ...	.	...	...	...	...	...	...	..	..	·3739	·4325	·430	·4299
8′ 6″—9′ 0″ ...		...	...	.	. .	.	...	...	...				

Statement No. II.

Grams of Water per c.c. of soil.

Depth.	1906.							1907.					
	19th Mar. No. 4.	2nd April No. 5.	19th July No. 40.	22nd Aug. No. 10.	9th Sept. No. 15.	20th Oct. No. 16.	30th Nov. No. 13.	8th Jany. No. 14.	15th Feb. No. 30.	27th Mar. No. 35.	6th May No. 27.	5th June No. 31.	15th June No. 36.
0″— 3″...	·2122	·1528	·2731	·3631	·3256	·2246	·210	·1702	·1974	·1657	·1211	·246	·1223
3″— 6″...	·1942	·2129	·2900	·3528	·2874	·2181	·245	·1761	·2188	·1741	·1599	·198	·1741
6″— 9″...	·2052	·2097	·2911	·3366	·2926	·2686	·192	·1786	·2065	·2162	·1670	·188	·1955
9″—1′ 0″...	·2583	·2822	·2947	·3366	·3100	·3003	·264	·2531	·1651	·3061	·2495	·257	·1748
1′ 0″—1′ 3″...	·3269	·2884	·3079	·3217	·3184	·3262	·304	·3049	...	...	...	...	...
1′ 3″—1′ 6″...	·2841	·2446	·3307	·3683	·3249	·2757	·305	·2893	·2965	·3450	·2000	·268	·2680
1′ 6″—1′ 9″...	·2388	·2026	·3599	·3948	·3508	·3262	·383	·2932	...	...	...	...	...
1′ 9″—2′ 0″ .	·1780	·1631	·2911	·4091	·3495	·3068	·258	·2757	·3139	·2233	·1812	·183	·1819
2′ 0″—2′ 3″...	·1871	·1282	·2751	·3933	·3618	·2647	·181	·2233	...	...	...	...	...
2′ 3″—2′ 6″...	·2013	·1184	·2777	·4576	·4091	·2589	·149	·1642	·1540	·1612	·1528	·154	·1288
2′ 6″—2′ 9″...	·2304	·1353	·3715	·4568	·4149	·3094	·157	·1580	...	...	...	...	...
2′ 9″—3′ 0″...	·1976	·1778	·4065	·5351	·4013	·3741	·198	·2214	·1987	·1603	·1773	·147	·1534
3′ 0″—3′ 6″ ..	·1116	·2666	·3127	·3461	·3988	·2852	·324	·2674	·2010	·1369	·0809	·079	·0851
3′ 6″—4′ 0″...	·2307	·1874	·3522	·4506	·4325	·2758	·264	·1667	...	...	·1292	·140	·1188
4′ 0″—4′ 6″...	·3331	·3332	·3862	·4400	·3985	·3678	·350	·3395	·3257	...	...	...	...
4′ 6″—5′ 0″...	·3318	·3190	·4073	·4976	·4234	·3911	·352	·3355	·3208	·3134	·2901	·260	·2665
5′ 0″—5′ 6″ ..	...	...	...	...	...	...	...	...	...	...	...	...	...
5′ 6″—6′ 0″...	...	...	...	...	...	...	...	...	·3958	·3752	·3480	·329	·3179
6′ 0″—6′ 6″ ..	...	...	...	...	...	...	...	...	...	...	...	...	...
6′ 6″—7′ 0″...	...	...	...	...	...	...	...	...	·4087	·4147	·4079	·384	·4066
7′ 0″—7′ 6″...	...	...	...	...	...	...	...	...	...	...	...	...	...
7′ 6″—8′ 0″...	...	...	...	...	...	...	...	...	·4107	·3593	·4212	·405	·4060
8′ 0″—8′ 6″...	...	...	...	...	...	...	...	...	...	...	...	...	...
8′ 6″—9′ 0″...	...	...	...	...	...	...	...	...	...	·3739	·4325	·430	·4299

Statement No. III.

Pounds of Water per c. ft. of soil.

Depth.	1906. 19th Mar. No. 4.	2nd April No. 5.	19th July No. 40.	22nd Aug. No. 10.	19th Sept. No. 15.	20th Oct. No. 16.	30th Nov. No. 13.	1907. 8th Jany. No. 14.	15th Feb. No. 30.	27th Mar. No. 35.	6th May No. 27.	5th June No. 31.	15th June No. 36.
0″— 3″ ...	13·25	9·54	17·05	22·67	20·33	14·02	13·11	10·63	12·32	10·34	7·56	15·36	7·64
3″— 6″ ...	12·12	13·29	18·11	22·02	17·94	13·62	15·30	11·00	13·66	10·87	9·98	12·37	10·87
6″— 9″ ...	12·81	13.09	18·17	21·01	18·27	16·77	11·98	11·15	12·89	13·50	10·43	11·72	12·20
9″—1′0″ ...	16·13	17·62	18·40	21·01	19·35	18·75	16·48	15·80	10·31	19·11	15·35	16·04	10·91
1′0″—1′3″ ...	20·41	18·00	19·22	20·13	19·88	20·37	18·98	19·04	...	...	...	...	...
1′3″—1′6″ ...	17·74	15·27	20·65	22·99	20·28	17·21	19·04	18·06	18·51	21·54	18·10	16·73	16·73
1′6″—1′9″ ...	14·91	12·65	22·47	24·65	21·90	20·37	17·67	18·30	...	...	...	...	...
1′9″—2′0″ ...	11·11	10·18	18·17	25·54	21·82	19·15	16·11	17·21	19·60	13·94	11·32	11·43	11·35
2′0″—2′3″ ...	11·68	8·00	17·17	24·56	22·58	16·53	11·30	13·94	...	...	...	...	...
2′3″—2′6″ ...	12·57	7·39	17·34	28·57	25·54	16·16	9·30	10·25	9·62	10·06	9·54	9·62	8·04
2′6″—2′9″ ...	14·38	8·45	23·19	28·52	25·90	19·32	9·80	9·86	...	...	...	...	...
2′9″—3′0″ ...	12·34	11·10	25·38	33·68	25·05	23·36	12·36	13·82	12·41	10·01	11·07	9·17	9·58
3′0″—3′6″ ...	6·97	16·64	19·52	21·61	24·90	17·81	20·23	16·69	12·55	8·55	5·05	4·52	5·31
3′6″—4′0″ ...	14·40	11·70	21·99	28·13	27·00	17·22	16·48	10·41	...	...	8·06	8·75	7·42
4′0″—4′6″ ...	20·80	20·80	24·11	27·47	24·88	22·96	21·85	21·20	20·33	...	...	...	...
4′6″—5′0″ ...	20·72	19·92	25·43	31·06	26·43	24·42	21·98	20·95	20·03	19·56	18·11	16·21	16·64
5′0″—5′6″ ...	...	...	...	...	...	...	...	...	...	...	...	...	...
5′6″—6′0″ ...	...	...	...	...	...	...	...	...	24·71	23·42	21·73	20·54	19·85
6′0″—6′6″ ...	...	...	...	...	...	...	...	...	...	...	...	...	...
6′6″—7′0″ ...	...	...	...	...	...	...	...	...	25·51	25·89	25·47	23·97	25·38
7′0″—7′6″ ...	...	...	...	...	...	...	...	...	...	...	...	...	...
7′6″—8′0″ ...	...	...	...	...	...	...	...	...	25·64	22·43	26·29	25·30	25·34
8′0″—8′6″ ...	...	...	...	...	...	...	...	...	...	...	...	...	...
8′6″—9′0″ ...		...	...	...	...	...		...	...	23·34	27·00	26·82	26·84

Statement No. IV.

Pounds of Water actually present in the soil.

Depth.	1906. 19th Mar. No. 4.	2nd April No. 5.	19th July No. 40.	22nd Aug. No. 10.	19th Sept. No. 15.	20th Oct. No. 16.	30th Nov. No. 13.	1907. 8th Jany. No. 14.	15th Feb. No. 30.	27th Mar. No. 35.	8th May No. 27.	5th June No. 31.	15th June No. 36.
0″— 3″ ...	3·31	2·38	4·26	5·67	5·08	3·50	3·28	2·66	3·08	2·58	1·89	3·84	1·91
3″— 6″ ...	3·03	3·32	4·53	5·50	4·48	3·40	3·82	2·75	3·22	3·40	2·49	3·07	2·72
6″— 9″ ...	3·20	3·27	4·54	5·25	4·57	4·19	2·99	2·79	3·22	3·40	2·61	2·93	3·05
9″—1′0″ ...	4·03	4·40	4·60	5·25	4·84	4·69	4·12	3·95	2·58	4·80	3·84	4·01	2·73
1′0″—1′3″ ...	5·10	4·50	4·80	5·03	4·97	5·09	4·74	4·76	(4·63)	(5·38)	(4·52)	(4·18)	(4·18)
1′3″—1′6″ ...	4·43	3·82	5·16	5·75	5·07	4·30	4·76	4·51	4·63	5·38	4·52	4·18	4·18
1′6″—1′9″ ...	3·73	3·16	5·62	6·16	5·47	5·09	4·42	4·60	(4·63)	(5·38)	(4·52)	(4·18)	(4·18)
1′9″—2′0″ ...	2·78	2·54	4·54	6·39	5·45	4·79	4·03	4·30	4·90	3·48	2·83	2·86	2·84
2′0″—2′3″ ...	2·92	2·00	4·29	6·14	5·64	4·13	2·82	3·48	(3·65)	(3·00)	(2·60)	(2·63)	(2·43)
2′3″—2′6″ ...	3·14	1·85	4·33	7·14	6·38	4·04	2·32	2·56	2·40	2·51	2·38	2·40	2·01
2′6″—2′9″ ...	3·59	2·11	5·80	7·13	6·47	4·83	2·45	2·46	(2·85)	(2·50)	(2·60)	(2·35)	(2·20)
2′9″—3′0″ ...	3·09	2·77	6·34	8·42	6·26	5·84	3·09	3·45	3·10	2·50	2·77	2·29	2·39
3′0″—3′6″ ...	3·48	8·32	9·76	10·80	12·45	8·90	10·11	8·34	6·27	4·27	2·52	2·26	2·65
3′6″—4′0″ ...	7·20	5·85	10·99	14·06	13·50	8·61	8·24	5·20	(5·00)	(5·00)	4·03	4·37	3·71
4′0″—4′6″ ...	10·40	10·40	12·06	13·73	12·44	11·48	10·92	10·60	10·17	(9·78)	(9·05)	(8·10)	(8·32)
4′6″—5′0″ ...	10·36	9·96	12·71	15·53	13·21	12·21	10·99	10·47	10·01	9·78	9·05	8·10	8·32
5′0″—5′6″ ...	...	...	(12·71)	...	(13·21)	(12·60)	(11·80)	(11·50)	(11·18)	(10·74)	(9·96)	(9·18)	(9·07)
5′6″—6′0″ ...	...	...	(12·71)	...	(13·21)	(13·00)	(12·70)	(12·50)	12·36	11·71	10·86	10·27	9·92
6′0″—6′6″ ...	...	...	(12·71)	...	(13·21)	(13·00)	(12·70)	(12·50)	(12·55)	(12·32)	(11·80)	(11·12)	(11·31)
6′6″—7′0″ ...	...	...	(12·71)	...	(13·21)	(13·00)	(12·70)	(12·50)	12·75	12·94	12·73	11·98	12·69
7′0″—7′6″ ...	...	...	...	...	...	...	...	...	...	...	...		...
7′6″—8′0″ ...	...	...	...	...	...	...	...	...	12·82	11·21	13·14	12·65	12·67
8′0″—8′6″ ...	...	...	...	...	...	...	...	...	...	...	...	...	...
8′6″—9′0″ ...	...	...	...	...	...	...	...	...	...	11·67	13·50	13·41	13·42

Statement No. X.

Ratio of Water to Surface, 19th March, 1906.

	0″—3″.	3″—6″.	6″—9″.	9″—1′ 0″.	1′ 0″—1′ 3″.	1′ 3″—1′ 6″.	1′ 6″—1′ 9″.	1′ 9″—2′ 0″.	2′ 0″—2′ 3″.	2′ 3″—2′ 6″.	2′ 6″—2′ 9″.	2′ 9″—3′ 0″.	3′ 0″—3′ 6″.	3′ 6″—4′ 0″.	4′ 0″—4′ 6″.	4′ 6″—5′ 0″.
Weight of 1 c.c. of soil in situ (grams) ..	1·302	1·316	1·354	1·393	1·346	1·258	1·273	1·210	1·311	1·298	1·255	1·191	1·256	1·385	1·462	1·427
Water per 1 c.c. of soil, 1 gram = 1 c.c. = W.	·2122	·1942	·2052	·2583	·3269	·2841	·2388	·1780	·1871	·2013	·2304	·1976	·1116	·2307	·3331	·3318
Sq. cm. of surface of 1 gram of soil ...	1419	1707	1956	2399	3441	3060	2360	1646	1478	1535	1597	1618	802	1641	2184	1976
Sq. cm. of surface of 1 c.c. of soil = S. ...	1847	2247	2649	3342	4633	3850	3005	1991	1937	1993	2004	1928	1007	2279	3194	2820
$\frac{W}{S} = R \times 10^5$	11·49	8·64	7·75	7·73	7·06	7·38	7·95	8·94	9·66	10·10	11·50	10·25	11·08	10·12	10·43	11·77

Statement No. XI.

Ratio of Water to Surface, 2nd April, 1906.

	0″—3″.	3″—6″.	6″—9″.	9″—1′ 0″.	1′ 0″—1′ 3″.	1′ 3″—1′ 6″.	1′ 6″—1′ 9″.	1′ 9″—2′ 0″.	2′ 0″—2′ 3″.	2′ 3″—2′ 6″.	2′ 6″—2′ 9″.	2′ 9″—3′ 0″.	3′ 0″—3′ 6″.	3′ 6″—4′ 0″.	4′ 0″—4′ 6″.	4′ 6″—5′ 0″.
Weight of 1 c.c. of soil in situ (grams) ...	1·402	1·430	1·454	1·350	1·254	1·232	1·243	1·297	1·298	1·304	1·300	1·260	1·294	1·291	1·462	1·380
Water per 1 c.c. of soil, 1 gram = 1 c.c. = W.	·1528	·2129	·2097	·2822	·2884	·2446	·2026	·1631	·1282	·1184	·1353	·1778	·2666	·1874	·3332	·3190
Sq. cm. of surface of 1 gram of soil ..	1402	1663	2206	2886	3138	2782	2406	1541	1228	869	932	1287	1760	1339	2356	1996
Sq. cm. of surface of 1 c.c. of soil = S. ...	1966	2378	3208	3896	3935	3427	2991	1999	1594	1164	1212	1623	2277	1729	3445	2755
$\frac{W}{S} = R \times 10^5$	8·91	8·95	6·54	7·24	7·33	7·14	6·77	8·16	8·04	10·17	11·16	10·96	11·71	10·84	9·67	11·58

Statement No. XII.

Ratio of Water to Surface, 19th July, 1906.

	0″—3″.	3″—6″.	6″—9″.	9″—1′ 0.″	1′ 0″—1′ 3″.	1′ 3″—1′ 6″.	1′ 6″—1′ 9″.	1′ 9″—2′ 0″.	2′ 0″—2′ 3″.	2′ 3″—2′ 6″.	2′ 6″—2′ 9″.	2′ 9″—3′ 0″.	3′ 0″—3′ 6″.	3′ 6″—4′ 0″.	4′ 0″—4′ 6″.	4′ 6″—5′ 0″.
Weight of 1 c.c. of soil in situ (grams) ...	1·383	1·416	1·317	1·266	1·244	1·335	1·436	1·265	1·307	1·289	1·341	1·305	1·317	1·387	1·460	1·458
Water per 1 c.c. of soil, 1 gram = 1 c.c. = W.	·2731	·2900	·2911	·2947	·3079	·3307	·3599	·2911	·2751	·2777	·3715	·4065	·3127	·3522	·3862	·4073
Sq. cm. of surface of 1 gram of soil ...	1812	1982	2587	2676	3076	3089	2871	1827	1246	1119	1247	1569	1179	2357	2316	1931
Sq. cm. of surface of 1 c.c. of soil = S. ...	2506	2806	3407	3388	3827	4124	4123	2311	1629	1442	1672	2049	1553	3269	3381	2815
$\frac{W}{S} = R \times 10^{6}$	10·90	10·34	8·54	8·65	8·05	8·02	8·73	12·60	16·89	19·26	22·22	19·84	20·14	10·77	11·42	14·47

Statement No. XIII.

Ratio of Water to Surface, 19th September, 1906.

	0″—3″.	3″—6″.	6″—9″.	9″—1′ 0″.	1′ 0″—1′ 3″.	1′ 3″—1′ 6″.	1′ 6″—1′ 9″.	1′ 9″—2′ 0″.	2′ 0″—2′ 3″.	2′ 3″—2′ 6″.	2′ 6″—2′ 9″.	2′ 9″—3′ 0″.	3′ 0″—3′ 6″.	3′ 6″—4′ 0″.	4′ 0″—4′ 6″.	4′ 6″—5′ 0″.
Weight of 1 c.c. of soil in situ (grams) ...	1·451	1·405	1·324	1·291	1·322	1·281	1·333	1·333	1·150	1·239	1·289	1·272	1·295	1·440	1·491	1·521
Water per 1 c.c. of soil, 1 gram = 1 c.c. = W.	·3256	·2874	·2926	·3100	·3184	·3249	·3508	·3495	·3618	·4091	·4149	·4013	·3988	·4325	·3985	·4234
Sq. cm. of surface of 1 gram of soil ...	1415	1740	2421	2792	2813	2822	2697	2405	1809	1815	1772	1424	773	2085	2295	1555
Sq. cm. of surface of 1 c.c. of soil = S. ...	2053	2445	3205	3605	3719	3615	3595	3206	2089	2249	2284	1811	1001	3002	3422	2365
$\frac{W}{S} = R \times 10^{6}$	15·86	11·75	9·13	8·60	8·56	8·99	9·76	10·90	17·39	18·19	18·17	22·16	39·84	14·41	11·65	17·90

Statement No. XIV.

Ratio of Water to Surface, 20th October, 1906.

	0″—3″.	3″—6″.	6″—9″.	9″—1′ 0″.	1′ 0″—1′ 3″.	1′ 3″—1′ 6″.	1′ 6″—1′ 9″.	1′ 9″—2′ 0″.	2′ 0″—2′ 3″.	2′ 3″—2′ 6″.	2′ 6″—2′ 9″.	2′ 9″—3′ 0″.	3′ 0″—3′ 6″.	3′ 6″—4′ 0″.	4′ 0″—4′ 6″.	4′ 6″—5′ 0″.
Weight of 1 c.c. of soil in situ (grams) ...	1·316	1·254	1·319	1·373	1·369	1·170	1·379	1·337	1·311	1·245	1·286	1·276	1·275	1·317	1·458	1·436
Water per 1 c.c. of soil, 1 gram = 1 c.c. = W.	·2246	·2181	·2686	·3003	·3262	·2757	·3262	·3068	·2647	·2589	·3094	·3741	·2852	·2758	·3678	·3911
Sq. cm. of surface of 1 gram of soil ...	1608	1874	2823	3014	3112	3025	2692	2119	1476	1364	1419	1438	1404	1215	2234	1994
Sq. cm. of surface of 1 c.c. of soil = S. ...	2116	2351	3724	4138	4260	3540	3711	2967	1935	1698	1825	1835	1790	1600	3257	2864
$\frac{W}{S} = R \times 10^6$	10·60	9·28	7·21	7·26	7·66	7·79	8·79	10·30	13·70	15·20	16·90	20·40	15·90	17·20	11·30	13·60

Statement No. XV.

Ratio of Water to Surface, 30th November, 1906.

	0″—3″.	3″—6″.	6″—9″.	9″—1′ 0″.	1′ 0″—1′ 3″.	1′ 3″—1′ 6″.	1′ 6″—1′ 9″.	1′ 9″—2′ 0″.	2′ 0″—2′ 3″.	2′ 3″—2′ 6″.	2′ 6″—2′ 9″.	2′ 9″—3′ 0″.	3′ 0″—3′ 6″.	3′ 6″—4′ 0″.	4′ 0″—4′ 6″.	4′ 6″—5′ 0″.
Weight of 1 c.c. of soil in situ (grams) ...	1·324	1·470	1·176	1·336	1·345	1·340	1·324	1·331	1·260	1·253	1·287	1·283	1·317	1·333	1·433	1·382
Water per 1 c.c. of soil, 1 gram = 1 c.c. = W.	·210	·245	·192	·264	·304	·305	·283	·258	·181	·149	·157	·198	·324	·264	·350	·352
Sq. cm. of surface of 1 gram of soil ...	1527	1883	2115	2857	3485	3258	2690	2031	1362	1064	1109	1273	1774	1469	2517	1987
Sq. cm. of surface of 1 c.c. of soil = S. ...	2022	2767	2490	3817	4688	4365	3561	2703	1716	1333	1427	1633	2336	1958	3608	2747
$\frac{W}{S} = R \times 10^6$	10·38	8·86	7·72	6·92	6·49	6·98	7·96	9·53	10·56	11·17	11·02	12·12	13·87	13·49	9·69	12·81

Statement No. XVI.

Ratio of Water to Surface, 8th January, 1907.

	0″—3″.	3″—6″.	6″—9″.	9″—1′ 0″.	1′ 0″—1′ 3″.	1′ 3″—1′ 6″.	1′ 6″—1′ 9″.	1′ 9″—2′ 0″.	2′ 0″—2′ 3″.	2′ 3″—2′ 6″.	2′ 6″—2′ 9″.	2′ 9″—3′ 0″.	3′ 0″—3′ 6″.	3′ 6″—4′ 0″.	4′ 0″—4′ 6″.	4′ 6″—5′ 0″.
Weight of 1 c.c. of soil in situ (grams) ...	1·333	1·410	1·280	1·281	1·311	1·253	1·339	1·333	1·305	1·270	...	1·338	1·312	1·314	1·496	1·447
Water per 1 c.c. of soil, 1 gram = 1 c.c. = W.	·1702	·1761	·1786	·2531	·3049	·2893	·2932	·2757	·2233	·1642	...	·2214	·2674	·1667	·3395	·3355
Sq. cm. of surface of 1 gram of soil ...	1465	1696	1718	2358	3295	2987	2826	3439	1926	1274	...	1493	1642	1095	2305	2004
Sq. cm. of surface of 1 c.c. of soil = S ...	1952	2391	2198	3020	4321	3743	3784	3252	2513	1618	...	1999	2155	1439	3448	2898
$\frac{W}{S} = R \times 10^5$	8·72	7·36	8·13	8·38	7·05	7·73	7·75	8·48	8·88	10·15	...	11·08	12·41	11·59	9·85	11·58

Statement No. XVII.

Ratio of Water to Surface, 15th February, 1907.

	0″—3″.	3″—6″.	6″—9″.	9″—1′ 0″.	1′ 3″—1′ 6″.	1′ 9″—2′ 0″.	2′ 3″—2′ 6″.	2′ 9″—3′ 0″.	3′ 3″—3′ 6″.	4′ 0″—4′ 6″.	4′ 6″—5′ 0″.	5′ 6″—6′ 0″.	6′ 6″—7′ 0″.	7′ 6″—8′ 0″.
Weight of 1 c.c. of soil in situ (grams)	1·364	1·422	1·346	1·035	1·298	1·412	1·278	1·243	1·278	1·437	1.427	1·522	1·459	1·451
Water per 1 c.c. of soil, 1 gram = 1 c.c. = W. ...	·1974	·2188	·2065	·1651	·2965	·3139	·1540	·1987	·2010	·3257	·3208	·3958	·4087	·4107
Sq. cm. of surface of 1 gram of soil	1477	1748	2055	2048	4061	3088	1267	1476	1012	2614	2223	2801	3947	3679
Sq. cm. of surface of 1 c.c. of soil = S.	2014	2486	2765	2120	5273	4359	1620	1834	1294	3756	3173	4263	5759	5340
$\frac{W}{S} = R \times 10^5$	9·80	8·80	7·47	7·79	5·62	7·20	9·51	10·83	15·54	8·67	10·11	9·28	7·10	7·69

STATEMENT No. XVIII.

Ratio of Water to Surface, 27th March, 1907.

	0″—3″.	3″—6″.	6″—9″.	9″—1′ 0″.	1′ 3″—1′ 6″.	1′ 9″—2′ 0″.	2′ 3″—2′ 6″.	2′ 9″—3′ 0″.	3′ 0″—3′ 6″.	3′ 6″—4′ 0″.	4′ 6″—5′ 0″.	5′ 6″—6′ 0″.	6′ 6″—7′ 0″.	7′ 6″—8′ 0″.	8′ 6″—9′ 0″.
Weight of 1 c.c. of soil in situ (grams) ...	1·328	1·276	1·402	1·504	1·482	1·297	1·017	1·084	1·199	1·457	1·391	1·493	1·550	1·484	1·283
Water per 1 c.c. of soil, 1 gram = 1 c.c. = W. ...	·1657	·1741	·2162	·3061	·3450	·2233	·1612	·1603	·1369	·3367	·3134	·3752	·4147	·3593	·3739
Sq. cm. of surface of 1 gram of soil ..	1451	1618	2274	3499	4162	2321	1360	1434	1005	2773	2238	3482	3371	3401	3661
Sq. cm. of surface of 1 c.c. of soil = S. ...	1926	2064	3188	5265	6166	3012	1383	1555	1207	4040	3122	5198	5226	5049	4700
$\frac{W}{S} = R \times 10^5$	8·60	8·43	6·78	5·81	5·59	7·41	11·66	10·31	11·34	8·33	10·04	7·22	7·93	7·13	7·96

STATEMENT No. XIX.

Ratio of Water to Surface, 6th May, 1907.

	0″—3″.	3″—6″.	6″—9″.	9″—1′ 0″.	1′ 3″—1′ 6″.	1′ 9″—2′ 0″.	2′ 3″—2′ 6″.	2′ 9″—3′ 0″.	3′ 0″—3′ 6″.	3′ 6″—4′ 0″.	4′ 6″—5′ 0″.	5′ 6″—6′ 0″.	6′ 6″—7′ 0″.	7′ 6″—8′ 0″.	8′ 6″—9′ 0″.
Weight of 1 c.c. of soil in situ (grams) ...	1·373	1·448	1·366	1·359	1·380	1·296	1·306	1·339	1·327	1·311	1·439	1·445	1·535	1·500	1·535
Water per 1 c.c. of soil, 1 gram = 1 c.c. = W. ...	·1211	·1599	·1670	·2459	·2900	·1812	·1528	·1773	·0809	·1292	·2901	·3480	·4079	·4212	·4325
Sq. cm. of surface of 1 gram of soil ...	1447	1652	1989	3225	3554	1983	1491	1740	765	1437	2160	2757	4012	3703	3713
Sq. cm. of surface of 1 c.c. of soil = S. ...	1988	2392	2718	4384	4905	2572	1947	2331	1016	1886	3110	3983	6158	5555	5700
$\frac{W}{S} = R \times 10^5$	6·09	6·68	6·15	5·61	5·91	7·04	7·86	7·60	8·96	6·85	9·33	8·74	6·62	7·58	7·5

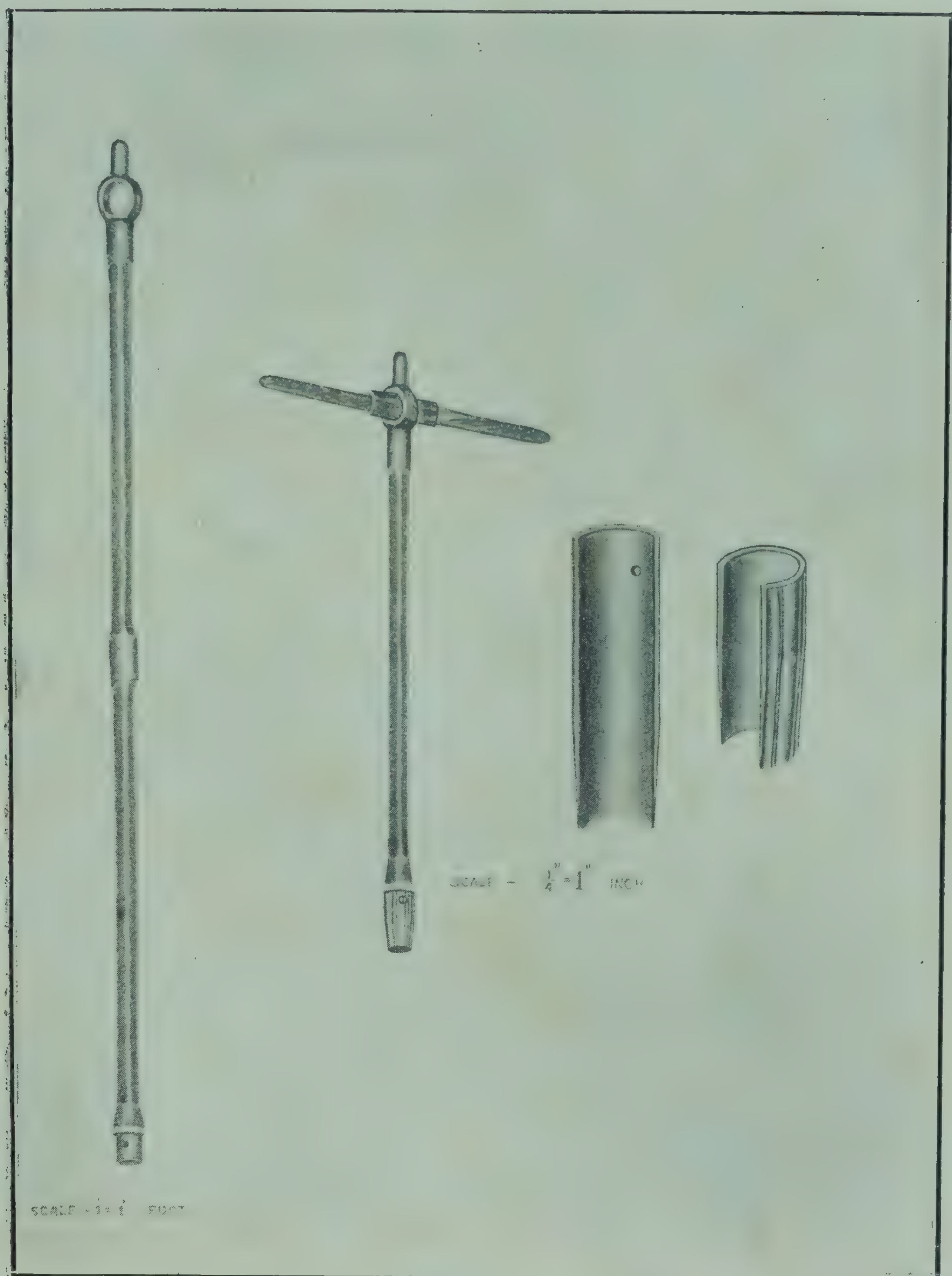

Fig. 2.—Boring tool.

Fig. 3.—Boring tool in use.

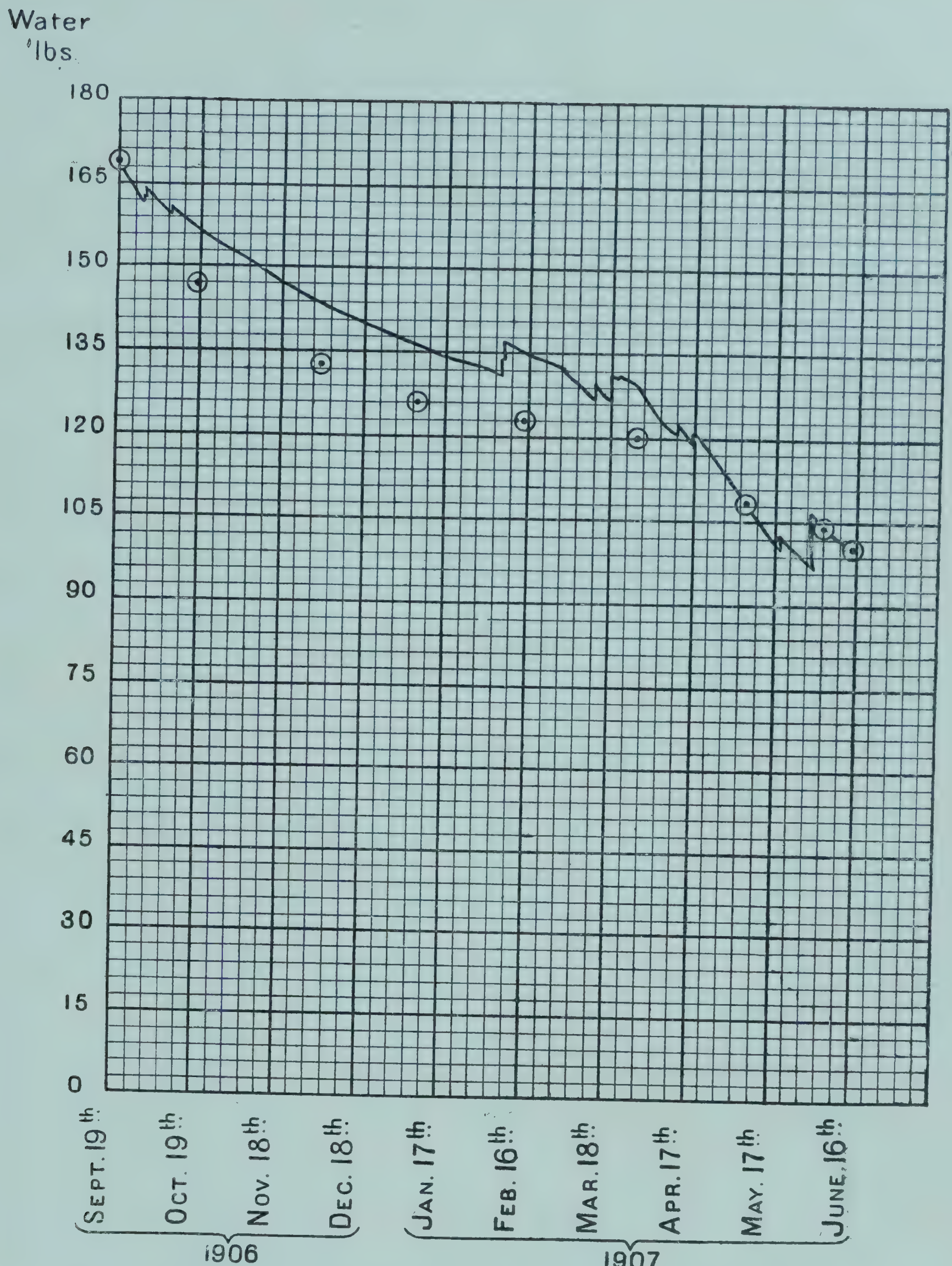

Fig. 4.—Curve showing calculated amount of Water in Pusa Soil, Sept. 1906 to June 1907.
⊙ = actual as determined.

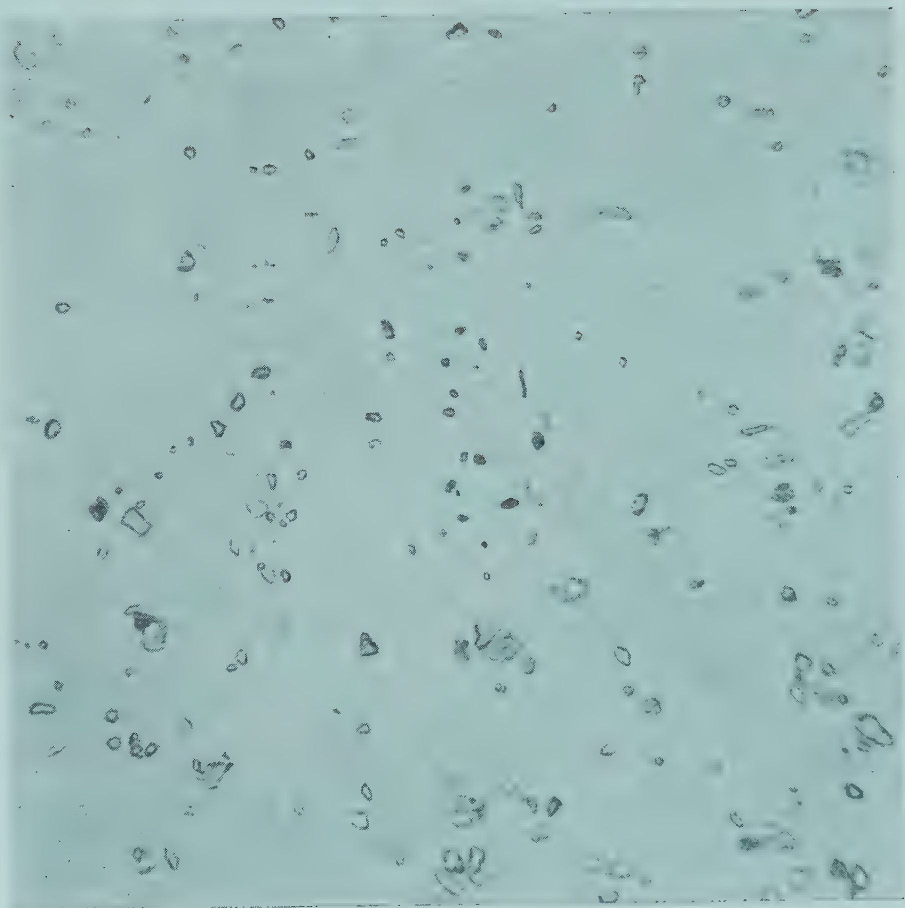

Fig. 5.—2 hrs. sediment × 400 diam. = ·002 – ·004 m.m.

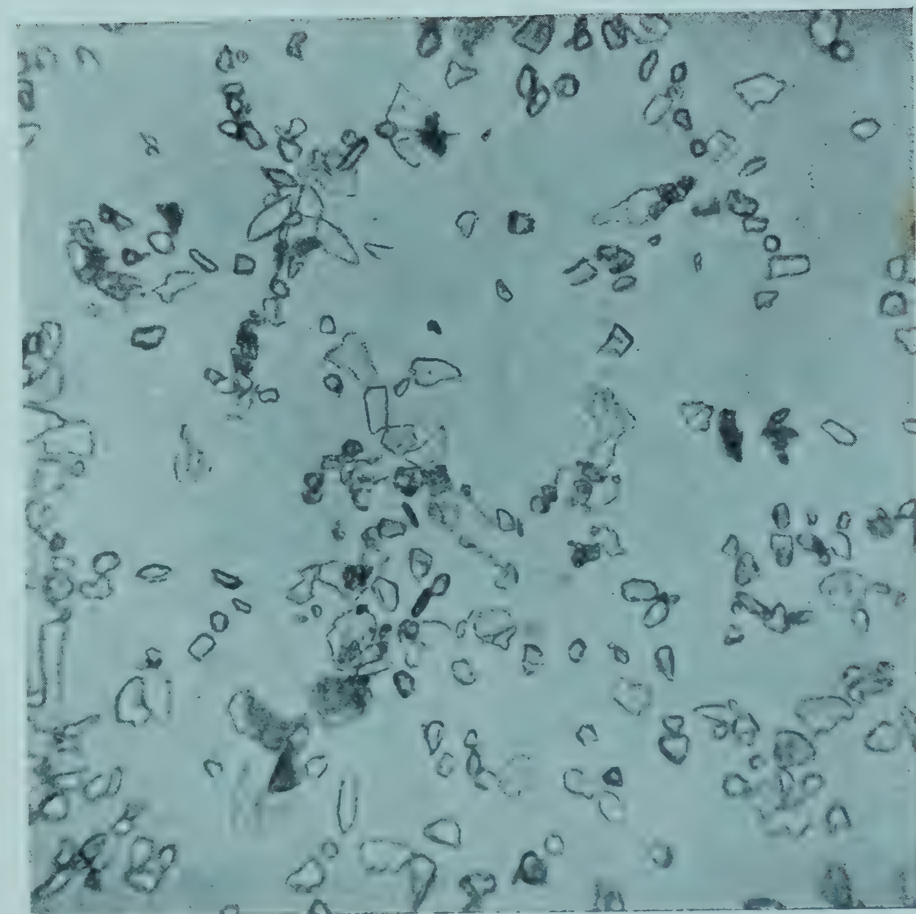

Fig. 6.—30 mins. sediment × 400 diam. = ·004 – ·008 m.m.

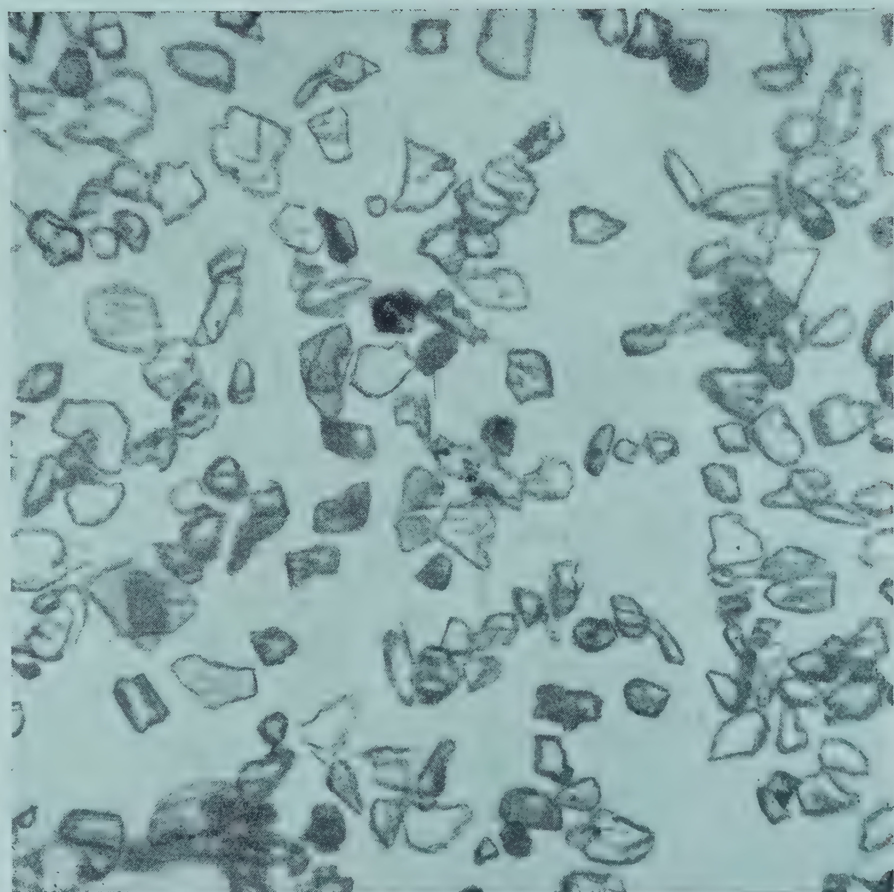

Fig. 7.—10 mins. sediment × 400 diam. = ·008 – ·016 m.m.

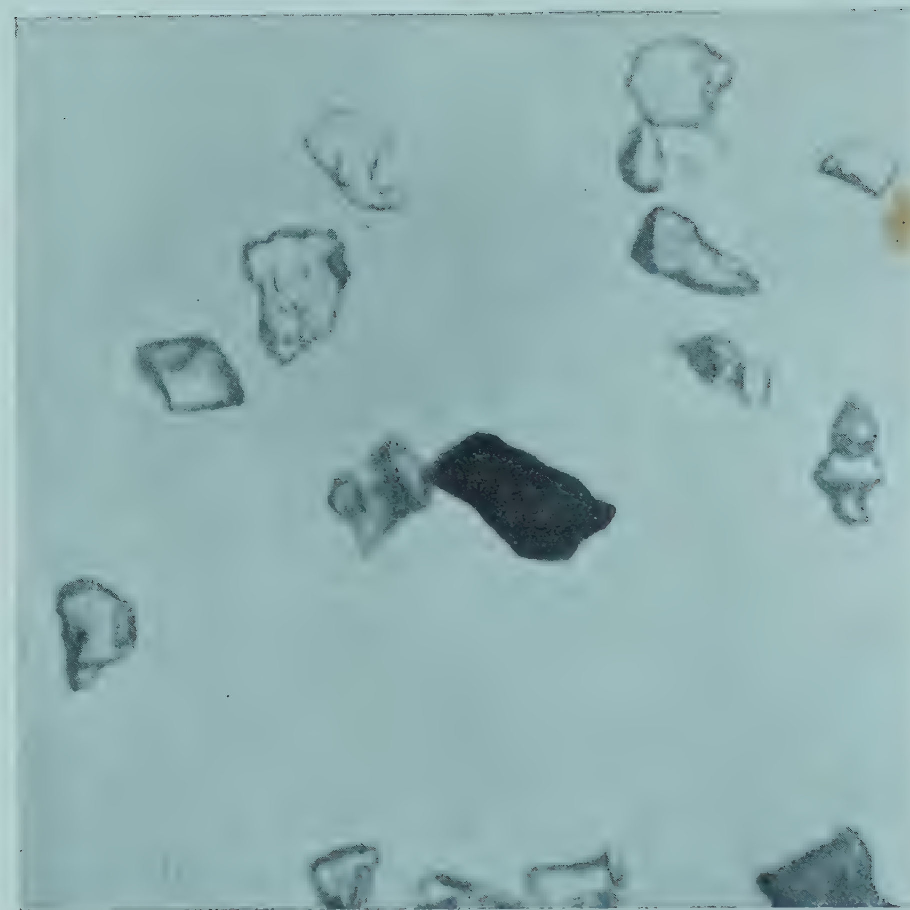

Fig. 8.—75 secs. sediment × 400 diam. = ·016 – ·032 m.m.

WATER REQUIREMENTS OF CROPS IN INDIA.

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Introduction.

In Chapter XI of their report, the Indian Irrigation Commission, 1901-03, remark: " In the course of our investigations we have been struck with the small amount of attention which appears to have been given by the Departments of Agriculture and Public Works to matters connected with the application of water to cultivated crops. At present most of the information which can be had on these points has to be taken from papers published by the Agricultural Bureau in America." It is indeed hardly necessary to dilate on the general importance of the subject in India where an efficient water-supply is, over at least very large areas, probably of greater importance than any other condition which appertains to its agriculture.

The subject of the water-supply to crops may, apart from rainfall or questions of irrigation systems, be conveniently subdivided under six heads :—

(1) the moistness of a soil for the purposes of germination and initial growth ;

(2) the total quantity of water required by a crop ;

(3) the period of growth during which a crop requires most water ;

(4) the amount of water which is contained in a soil ;

(5) the proportion of this which is available to crops ;

(6) the effect on *the development of a crop* of varying proportions of water in any specified soil.

The information contained in this Memoir relates to the *second* and *third* of these subjects.

The vegetable physiologist has devoted attention largely to the organs of plants which chiefly control transpiration. He has compared the process with the relative abundance of the stomata, has estimated the relative activity in this respect of the upper and lower side of the leaf, the activity of the parenchyme, the function of hairs and the like. In such investigations the water transpired is commonly referred to the leaf area, or to a unit area of leaf, or equal parts of a plant have been employed and the quantities of water transpired in equal periods of time have been compared. But for the end which we have in view, namely, an estimate of the water required by crops, such investigations can only have an indirect value. Experiments have also been made on the effects of light of different refrangibility, of temperature, and of humidity. Whilst the first of these has no direct bearing on our subject, the second and third are important, but a knowledge of their influence during the whole growing period is required rather than at individual times. Indeed, experiments have been so commonly made for short periods of time and so frequently with parts of plants of non-agricultural interest, rather than with the more important field crops, that much of what has been published on transpiration of water becomes of little direct use to us. It will be well to emphasise the limits of the subject we are to deal with. It is simply "How much water is transpired by our several field crops?" and "during what period does the crop require the principal portion of this water?" Several experimenters have estimated the former, whilst as to the latter question, although deductions may be made from published data, attention does not appear to have been directed to it specially.

As regards the total quantity of water involved, it is to be anticipated that a large plant or crop will transpire more water than a small one of the same kind. Consequently it becomes essential to adopt a mode of expressing our quantities which will make them applicable to all general cases.

Those who have dealt with the subject which we have in hand, have uniformly referred *the water transpired to the weight of dry plant produced*, and have expressed the relation between these two quantities as a *Ratio*, namely, the parts by weight of water transpired per 1 part of dry plant substance produced. This is the *Transpiration Ratio*. Thus, if the transpiration ratio of wheat were stated to be 500, it would imply that for each pound or ton of wheat crop grown, including the grain, chaff and straw, (but not the root) 500lbs. or tons of water would be transpired. It is then a simple matter to calculate the quantity per acre; for instance, say a wheat crop weighed 4,000lbs. per acre, and the transpiration ratio were 450, then the weight of water transpired per acre would be $4{,}000 \times 450 = 1{,}800{,}000$lbs. or $\frac{1{,}800{,}000}{2{,}240} =$ 804 tons or, since an acre of water 1″ deep weighs (approximately) 227,000lbs. $\frac{1{,}800{,}000}{227{,}000} = 7{\cdot}95$ inches. This is the simplest mode of stating the information and is adopted in this publication in so far as the first of our two subjects is concerned.

Reference may now briefly be made to the work of others. The transpiration ratio of field crops has been determined at four Agricultural Stations, namely, at Rothamsted (1848) by Lawes, at Dhame (1867—72) by Hellriegel, at Munich (1876) by Wollny, and at Wisconsin (1891-92) by King.

Their results may be suitably summarised thus:—

STATEMENT I.

	Lawes Ratio.*	Hellriegel Ratio.†	Wollny Ratio.‡	King Ratio.§
Wheat	247	338	...	...
Barley	257	...	774	393
Oats	...	376	665	522
Rye	...	353	...	...
Maize	...	...	233	310
Beans	209	282	...	...
Peas	259	273	416	477
Clover	269	310	...	453
Buckwheat	...	363	646	...
Colza	...	329	912	...

* Jour. Horticultural Soc. V (1850).

† Grundlagen des Ackérbaues, p. 622, et seq.

‡ Einfluss der Pflanzendecke und Beschattung auf die physikalische Eigenschaften und die Fruchtharkeit des Bodens, p. 125.

§ Rep. Wisconsin Expt. Stn., 1894, p. 248

From the papers which these authors published it appears that the amount of water transpired is very large, that it is greatest during the period of rapid leaf development and until the fruit is formed after which it declines, and that it is affected by temperature, atmospheric humidity and the supply of plant-food.

It is evident, however, that, inasmuch as Indian climatic conditions are so widely different from those of the Agricultural Stations mentioned, the above transpiration ratios would in any case require careful check by experiments made in India before they could be employed with any confidence here. And this is the more desirable because of the very considerable differences which occur in the values of the published ratios.

The question as to whether plants transpire more, or less, water in the tropics than in Europe, has indeed formed the subject of a number of experiments and discussions since 1892. Haberlandt, from experiments made at Buitenzorg in Java and at Graz in Holland, concluded that the transpiration is much less in the "moist-warm" climate of West Java than in middle Europe. Against this opinion Gitlay, Burgerstein, Holtermann and others have quoted experiments which contradict such a conclusion. It seems that all the observations related to amounts of water transpired during short intervals of time such as a couple of hours, and were for the most part referred to the area of leaf surface involved; also that many of the experiments were made with parts of plants. The limitation of the work has been fully recognised by Burgerstein who says (page 173) "dass es nicht angeht, die in absentia solis für ein paar Tage ermittelte transpiration abgeschnittener Zweige oder Blätter von ein paar Pflanzenarten für die tatsächliche Jahresleistung eines ganzen Vegetations gebietes zu substituieren." (*Trans.:* that it is not legitimate to substitute for the actual yearly requirement of a whole vegetable region, the transpiration of isolated twigs or leaves of a couple of plant varieties, which has been ascertained in the absence of direct sunlight during a couple of days). It is obvious that the factors which control the water requirements of any particular crop are so numerous and the value of each so

difficult to determine with even approximate precision, that it seems unreasonable to deduce it for one country from observations made in another of entirely different climate. The data which we have obtained at Pusa do in fact show that the total water requirement of some of the crops grown during the moist period of the S. W. monsoon is distinctly smaller than those grown during the cold weather, and thus support in part Haberlandt's argument, but it is equally certain that the corresponding requirements of other crops grown at the same period are much larger. The nature of the plant is an important factor.

For several years records of the amount of water which plants, specimens of our field crops, transpire throughout their period of growth have been maintained at Pusa by means of "pot-cultures," and comparison of these data showed that they were so regular that, apart from other evidence, they might properly be accepted as a means of calculating the total quantity of water required. It will probably be most convenient to the reader if the subject-matter is divided as follows :—

(*a*) method employed ;

(*b*) data obtained ;

(*c*) examination of the data with a view to establishing the effect of various influencing factors.

METHOD EMPLOYED.

Pot-cultures.—The Pot-culture House at this Institute and its adjuncts have been described in Memoir No. 3 (Chem. Series) and it will therefore suffice if details of the method followed are given.

The cultivation jars.—These are glazed stoneware and have the following dimensions :—

Size.	Diameter, inches.	Depth, inches.	Soil capacity, kilos. (Approx.)
A	9	12	14
B	9	16	22
C	9	22	29
D	12	16	31
E	12	22	50

Filling the jar.—The soil is always damped before being packed into the jar, because experience has shown that the water subsequently added becomes distributed much more uniformly if this procedure is adopted than if the soil is packed in air-dry. As regards the degree of moistness, discretion has to be used, for soils vary within wide limits in the amount of water required to make them moist; but, roughly speaking, sufficient water is carefully worked into the soil to make it just adhere together when pressed in the hand, without running the risk of it "puddling." Some soils are packed into the jars by pressing with the fist, others such as the Black cotton soil, are best only shaken into the jar. After filling the damped soil into the jar, water is added in quantities of about half a litre per day until the desired quantity has been introduced.

Mode of adding water.—In these experiments the water was always added by means of unglazed earthenware cylinders of about 2″ diameter and from 6″ to 10″ deep, provided with small holes in the bottom and lower part of the sides. These cylinders are fixed in position in the centre of the soil when filling the jar, so that the upper edge coincides approximately with that of the jar. By this means the surface soil remains loose, friable, and nearly air-dry, and cracking is thus avoided. The direct loss of water from the soil surface is at the same time much reduced. Experiments which have been made to test this latter point have shown that the loss of water from this cause has been reduced to about one-third by the use of these cylinders of what it would have been had the water been added at the surface of the soil.

In some soils, however, experience has shown that the surface becomes air-dry to such a degree by this method of watering, that the germination of the seed and the initial development of the young plant are interfered with, and consequently in such cases water is added at the surface until the plant is established, after which water is best supplied by the cylinders. The question naturally arose as to whether the root development occurred principally in the immediate neighbour-

hood of the cylinder. It was suspected that this might take place just where the water was introduced, but examination of the root systems has shown that the principal development is at the bottom of the jar, or at least below the cylinder and fully as much at the sides of the jar as near the cylinder. No particular accumulation of root has been found about these cylinders.

The water employed.—Clean well water has been used throughout.

Addition of fertilizers.—Wherever fertilizers are used, these are added either in the dry state to the air-dry soil before it is damped for filling, or the substance is dissolved in the water used for damping the soil.

Sowing seed.—From ten to twenty seeds are usually sown at regular space intervals immediately the jars are filled with soil.

Thinning.—After the seed has germinated and the plants fairly established, they are reduced in number and again further reduced a few days later to a small number, such as three or four; these are allowed to mature. This "thinning out" of the plants has been always (except in the first and second seasons) completed before the amount of water transpired became of material consequence. In the first and second seasons when this was not done, the thinned out plants were weighed and allowance for the water they had transpired was made in the final calculations.

Weighing.—The jars have been weighed *every morning* throughout the whole period of growth.

In each case the weight of jar, soil and water are known and these together form the "standard weight"; where the weight of the plant is so considerable that this should be included in order to avoid any serious error, an estimate of it is made and the "standard weight" increased accordingly. Usually this is unnecessary.

After recording the weight of the jar, the difference between this and the standard weight gives the weight of water transpired by the plant and lost by the soil during the preceding 24 hours, and this quantity of water is added so that the standard moistness of the soil is reinstated.

Control jars of soil.—The water lost from a jar of soil with plants growing in it is necessarily the sum of that transpired by the plants and that lost directly by evaporation from the soil. Our object is to estimate the former quantity.

Most experimenters on the subject of transpiration have employed *covered* jars in order to reduce the direct loss from the soil to a minimum. Thus Lawes placed glass plates, having holes in them for the plants to grow through, over the soil and cemented them to the edge of the jar. Hellriegel also in his later work employed close covers.

This device has not been employed at Pusa. In our experiments over 100 cultivations have been maintained at one time, and it would not only have increased the cost of the apparatus very considerably to provide such covers, but would in practice have been all but impossible of application at the time of filling jars and sowing. A much more serious matter is, however, the fact that by covering up the surface of the soil, normal aeration becomes suspended; and although our information regarding the value to a growing crop, of aeration of agricultural land is most imperfect, the suspension of this process would throw a doubt on the value of the work. Finally, it was ascertained that the loss of water from the soil is very regular, and is so small in comparison with that transpired by a heavy crop, that sufficiently exact information as to its magnitude may be ascertained by maintaining jars of the same soil containing the same proportion of water as that employed in the series of cultures. The error only assumes material proportions in the case of small stunted plants, and, as will become evident, this is of small consequence.

The method adopted is briefly this. For each experiment (except during the first season) a jar of the same size containing the same soil has been maintained at the same degree of moistness throughout the period of growth and the daily loss of water registered against the total loss from the other jars of the series. For the experiments with a number of crops grown in the same soil *four* such jars (two of which were manured) were used.

Now it is not to be expected that the soil of a series of jars, even though all are filled alike with the same soil and maintained with the same proportion of water, will evaporate exactly the same amount of water, and the records of the four jars mentioned provide an index of this difference. For example, during the growing period of the Juar last year, June 15th to November 11th, these four jars lost 9·93, 10·68, 13·03, and 14·11 kilos respectively. (It may be mentioned here that these differences are not in any way due to the presence of manure in the soil.) The arithmetical mean of these is assumed to be the amount of water which has evaporated directly from the soil during the experiment. This method of estimating the factor is naturally not perfect but is more free from defects than any other and yields results which, at least for all well grown plants, are subject to an experimental error of not more than 5%. The corresponding error for poorly developed ones is larger, but the correctness of the transpiration ratio is not of great consequence in such cases.

Protection from rain.—All jars are brought under cover in wet weather, as also at night.

Harvesting.—As the plants matured, they were cut off close to the root, air-dried, the seed finally separated, the whole weighed, and the remaining moisture determined. The weight of the material was then reduced to the dry state. In a few cases, (guar) cyamopsis psoralioides, and (arhar) cajanus indicus, some of the pods ripened before the remainder of the plant ; in these the pods were removed as they ripened, so as to avoid losing them.

Effect of the sun's heat on the jars.—One of the criticisms which have been made on the pot-culture method for the determination of the transpiration ratio is that, since the jars are exposed to the direct rays of the sun, and the temperature of the soil is in consequence exposed to greater fluctuations than would occur in the field, a serious error is probable.

In order to test this question certain jars of maize in 1907 and of wheat in 1907-08 were maintained in large boxes surrounded with 5″—7″ saw-dust throughout the period of growth ; with which exception, however, the conditions

corresponded with other jars fully exposed. The results are summarised thus :—

STATEMENT II.

Protection.	Water in soil.	Manure used.	Dry crop, grms.	Water transpired, kilos.	Ratio.
			Maize. 1907.		
Exposed to sun	20%	*Nil*	11·26	6 81	606
Protected	..	,, ...	8·2	5·15	630
Exposed to sun	...	Nitrate and phosphate ..	35·82	13·7	382
Protected	...	,, ,,	40·95	17·30	428
			Wheat 1907-08.		
Exposed to sun	20%	*Nil*	8 58	9·72	1133
Protected	...	,, ...	8·33	8·45	1014
Exposed to sun	...	Rape cake and phosphate	38·49	27·91	725
Protected	...	,, ,,	43·22	35·97	832

An examination of these data show that the exposure of the jars to the sun had no influence on the ratio.

Diurnal variation of water content in soil.—Although it was arranged to maintain a certain degree of moisture in the soil, it is obvious that as transpiration proceeds during the day, a decrease must occur in this proportion of water, and it is of interest to note how much this was. As in all such calculations, it is preferable to take maximum figures. Accordingly we may select instances from the largest and the most vigorous plants growing in the smallest jars. Such for example were the manured peas ; these transpired about 1 kilo of water per day for a short time. The soil contained (at 20%) 2·72 kilos of water, so that during the day the amount of water decreased to about 1·7 kilos when the percentage in the soil would be about $12\frac{1}{2}$. This is naturally a great variation, but the experiments of the cold weather 1906-07 and the monsoon 1907 have shown that the transpiration ratio is not affected, within certain limits, by the amount of water in the soil, and those limits were not exceeded. But in most cases the diurnal percentage variation was considerably less than this, and in the large jars of soil it was only nominal.

PART II.

Details of Pot-cultures.

Inasmuch as a large part of the records obtained by pot-cultures lend themselves to tabular statement, this method has been here adopted and the chief data are so exhibited in the following pages. In most cases a chart is added showing the daily weight of water lost throughout the growing period together with its relation to the atmospheric humidity. Illustrations of most of the plants themselves are likewise added.

Apart from data, there are however several other matters which require explanation.

General synopsis of the experiments.—In the first season, the cold weather 1906-07, wheat was grown in Pusa soil in two sizes of jars. In each of these sets of jars three different proportions of water in the soil were maintained, and the jars of each of these sub-divisions were differently manured. It was intended to grow lucerne in two others, but the first seed used did not germinate, and in order to avoid losing a season, new lucerne was sown in only one set of the jars, and Cicer arietinum (Gram) in the other. The lucerne grew well at first, but failed later; the gram was more or less diseased. In the following monsoon period maize was selected for the experiments and was grown in Pusa soil. Here three sizes of jar were employed, three different proportions of water were maintained in each set and the soil of each sub-division was differently manured. An examination of the data thus obtained during two seasons seemed to indicate one or two general conclusions. The depth or quantity of soil employed, affects the size of the plant, and seemed to have a moderate influence on the transpiration ratio; the effect of different proportions of water in the soil was not appreciable. On the other hand, the effect of a fertilizer containing nitrate and phosphate had in both seasons a very marked influence on the ratio. Another marked difference was noticed between the transpiration ratio for wheat and maize respectively, the former being materially larger than the latter. During the next season, the cold weather

of 1907-08, it was decided to check the results obtained with wheat. For this purpose it was grown in Pusa soil in two sizes of jar; in each set two different proportions of moisture in the soil were maintained, and the soil of each subdivision was differently manured; in this case, however, oil-cake was used instead of calcium nitrate or calcium cyanamide. These experiments fully substantiated the first in all important respects, and it was decided to enlarge the scope of the experiments particularly in two respects; firstly, to employ a variety of soils as different from one another as possible, in which the same plant would be grown; secondly, to employ half a dozen of the chief field crops, all of which would be grown in the same soil. The former list included, in addition to the highly calcareous Pusa soil, a black cotton soil, a soil containing an unusually high proportion of organic matter and two rather sandy soils. Details regarding this section of the investigation will be the subject of a future communication. The ratios obtained with maize during the monsoon were quite regular and indicated that the nature of the soil has either no influence or at most only a nominal influence on the transpiration ratio. The cold weather ratios, obtained with wheat, proved irregular in some respects and make it necessary to repeat this section of the work.

For the second section of the work a number of different crops were grown in Pusa soil. The plants employed were seven during the monsoon of 1908, namely, zea mais (maize), oryza sativa (rice), andropogon sorghum (the big millet juar), the two small millets, eleucine coracana (murwa, ragi) and paspalum scrobiculatum (kodo) and two pulses, cajanus indicus (arhar, tur) and cyamopsis psoralioides (guar). Similarly during the succeeding cold weather, 1908-09, seven other plants were included, namely, wheat, oats, barley, linseed, B. campestris (sarson), peas and cicer arietinum (gram). Regarding the general growth of the plants, the following brief remarks may be made:—In nearly all cases germination was regular. Most plants develop very well in the small jars (size A), but maize forms a conspicuous exception and does not form cobs

properly in these. As will be seen by reference to the data, this fact seems to have affected the transpiration ratio in only a moderate degree. The large millet juar, though it did better than maize, was not a really good specimen. But all the other plants, even the large pulse, arhar, have grown to great perfection. The latter grew 8 feet high and wheat about 4 feet high in the manured soil in these small jars.

Duplication of jars.—During the first three seasons no experiment was duplicated, dependence being placed on a single jar in each case, but the results obtained did in fact substantiate one another indirectly because several of the conditions, such as proportion of water in the soil, proved to exert no very great influence on the transpiration ratio. In the following seasons, the monsoon 1908 and the cold weather 1908-09, only one proportion of moisture was adopted in any one case, and duplication of jars was more necessary. An examination of the data show that such duplication is an advantage, but the number of cases where a serious difference in the result occurs is only very small. For the purpose of a ready comparison of the data, the statements have been arranged according to the nature of the plant, in the following order :—

Cold weather season	Wheat Barley Oats Linseed Sarson Peas Gram
Monsoon crops...	Maize Juar Rice Marwa Kodo Arhar Guar

The data for wheat which has been grown during three seasons are arranged chronologically ; and the same has been adopted for maize which has been grown during two seasons.

The numbering of the plates and charts in this Memoir is such that the same number is given to the statement, the plate, and the chart of any one crop, and consequently some plate and chart numbers are absent from the Series; for example, there are no plates or charts corresponding to statements I and II; there is no chart No. III; there is no plate No. IX, etc.

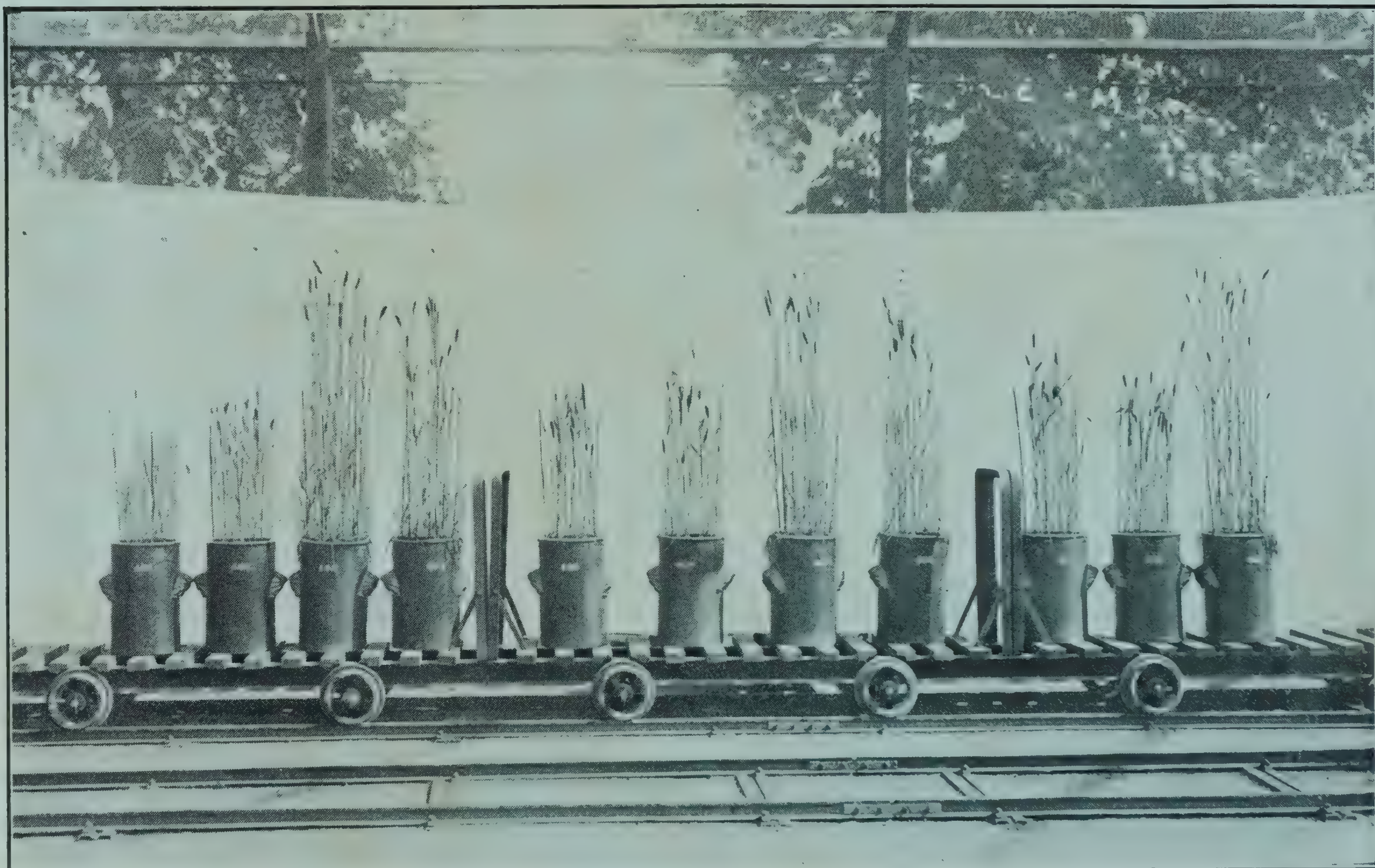
STATEMENT III.

Triticum sat. (Wheat) 1906-07.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of		Dry crop.		Water trans-pired Kilos.	Ratio.
					Sowing.	Harvest.	Seed. Grms.	Total. Grms.		
101	A=9″ diam. ×12″ deep.	About 15 kilos. of Pusa soil.	10	Nil	23-10 06	22-4-07	2·5	9·6	8·65	900
102			10	N	23-10-06	22-4-07	1·8	11·3	11·83	1,050
103			10	N+P	23-10-06	5-4-07	13·0	41·0	22·26	543
104			10	N+P+K	23-10-06	5-4-07	12·4	43·2	22·72	527
105			15	Nil	23-10-06	22-4-07	1·9	8·4	5·48	653
106			15	N	23-10 06	22-4-07	2·1	13·5	12·72	944
107			15	N+P	23-10-06	5-4-07	13·0	40·5	21·85	540
108			15	N+P+K	23-10-06	5-4-07	11·9	39·9	20·56	515
109			20	Nil	23-10-06	22-4-07	3·7	15·6	12·90	829
110			20	N	23 10 06	22-4-07	3·3	8·1	18·07	1,000
111			20	N+P	23-10 06	5-4-07	15·1	53·3	30·63	574
112			20	N+P+K	23-10-06	5-4-07	12·0	44·7	26·05	583
C=Ca $(NO_3)_2$=·005 grm. N; P=superposphate = ·01 grm. soluble P_2O_5 and K=K_2SO_4=·005 grm. K_2SO_4 per 100 grm. soil.										
401	B=9″ diam. × 16″ deep.	About 22 kilos. of Pusa soil.	10	Nil	24-10 06	22-4 07	3·9	16·2	15·25	941
402			10	N	24-10-06	22-4 07	2·1	14·9	12·41	806
403			10	N+P	24-10-06	5-4-07	23·3	72·3	42·91	593
404			10	N+P+K	24-10-06	5-4-07	15·2	50·2	30·82	614
405			15	Nil	24-10-06	22-4 07	4·8	22·0	23·32	1060
406			15	N	24-10-06	22-4 07	4·8	22·5	18·83	837
407			15	N+P	24-10 06	5-4 07	24·4	79·1	39·88	504
408			15	N+P+K	24-10-06	5-4-07	18·1	54·7	33·05	604
409			20	Nil	24-10-06	22-4-07	6·8	29·5	28·17	955
410			20	N	24-10-06	22-4 07	5·3	21·5	18·60	865
411			20	N+P	24-10-06	5-4-07	28·4	86·9	44·62	515

N=Ca CN_2=·005 grm. N per 100 grms. soil; P=superphosphate=·01 grm. soluble P_2O_5
K=K_2SO_4=·005 grm. K_2O per 100 grms. soil.

PLATE III.



WHEAT, 1906-7.

PLATE IV.

WHEAT, 1907-8.

504, 508. Oil Cake and Superphosphate.
503, 507. Oil Cake.
502, 506. No manure.

STATEMENT IV.

TRITICUM SAT. (WHEAT) 1907-08.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of Sowing.	Date of Harvest.	Dry Crop. Seed. Grms.	Dry Crop. Total. Grms.	Water transpired. Kilos.	RATIO.
1	A = 9″ diam. × 12″ deep.	About 15 kilos of Pusa soil.	10	Blank	Jar.				(3·13)	
2			10	Nil.	31-10-07	30-3-08	3·65	12 31	7·80	634
3			10	Rape cake	31-10-07	30-3 08	13 79	42·20	22·08	523
4			10	Rape cake and superphosphate.	31-10 07	30-3-08	14·66	42·85	24·45	571
5			20	Blank	Jar.					
6			20	Nil.	31-10 07	6-4-08	1·79	8·58	9 72	1133
7			20	Rape cake	31 10 07	30-3-08	10 87	34·11	24·72	725
8			20	Rape cake and superphosphate.	31-10 07	30-3-08	12·71	38·49	27·91	725
501	C = 9″ diam. × 22″ deep.	About 29 Kilos of Pusa soil.	10	Blank	Jar.				(7·03)	
502			10	Nil.	30 10 07	6-4-08	5·02	16. 5	11·49	696
503			10	Rape cake.	30 10-07	30-3-08	15·19	47.84	23 92	500
504			10	Rape cake and superphosphate.	30-10-07	30-3 08	22·37	67·03	29 90	446
505			20	Blank	Jar.					
506			20	Nil.	30-10-07	6-4 08	4·83	23·31	19·14	821
507			20	Rape cake.	30-10 07	30-3-08	37·99	132·79	76·42	575
508			20	Rape cake and superphosphate.	30 10-07	30-3 08	33·55	120·44	60·87	505

The *Rape cake* used was equivalent to ·005 grm. N. per 100 grms. soil; the superphosphate was sufficient to increase the phosphate in the manure to ·01 grm. soluble phosphoric acid per 100 grms. soil.

CHART IV*a*.

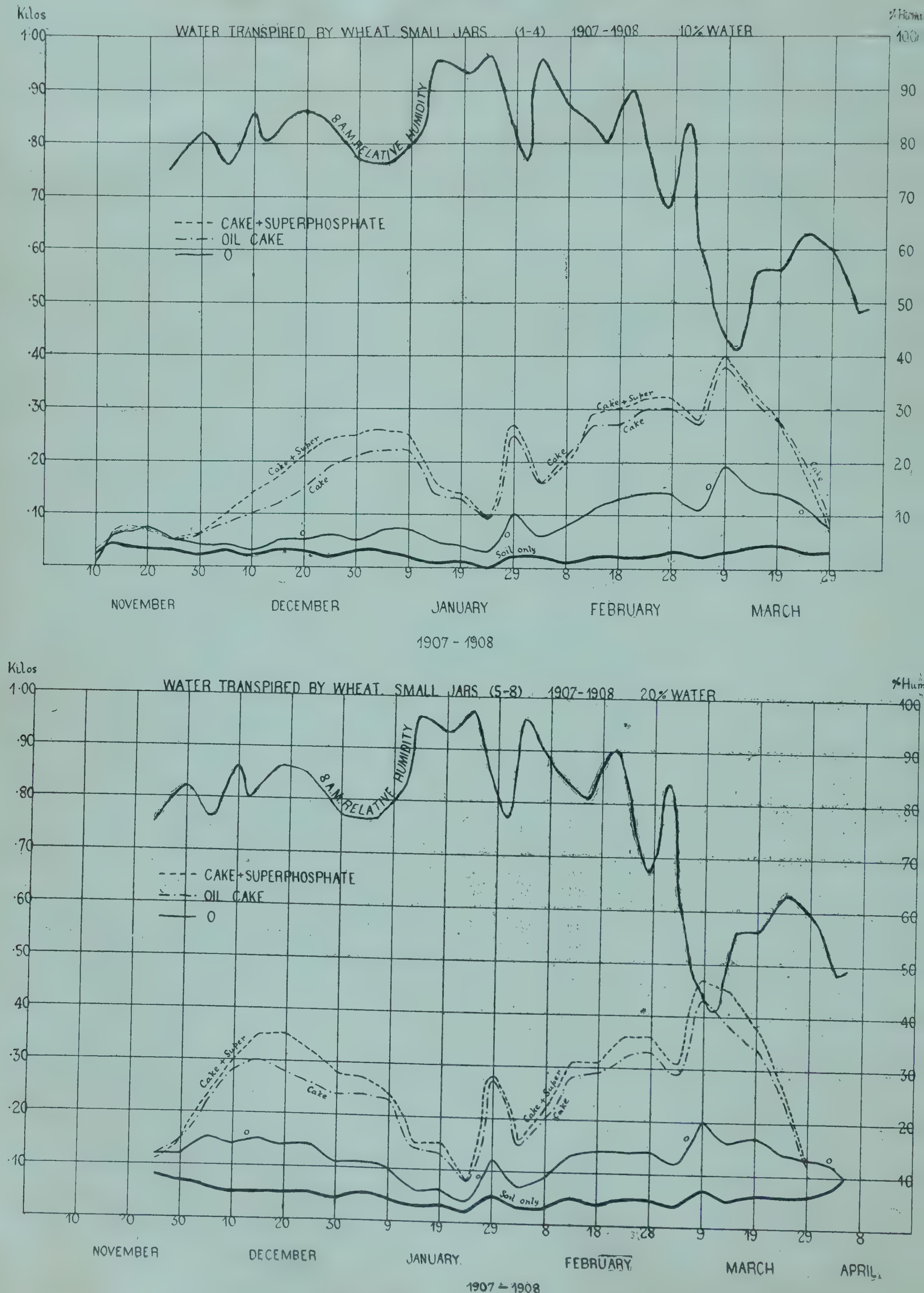
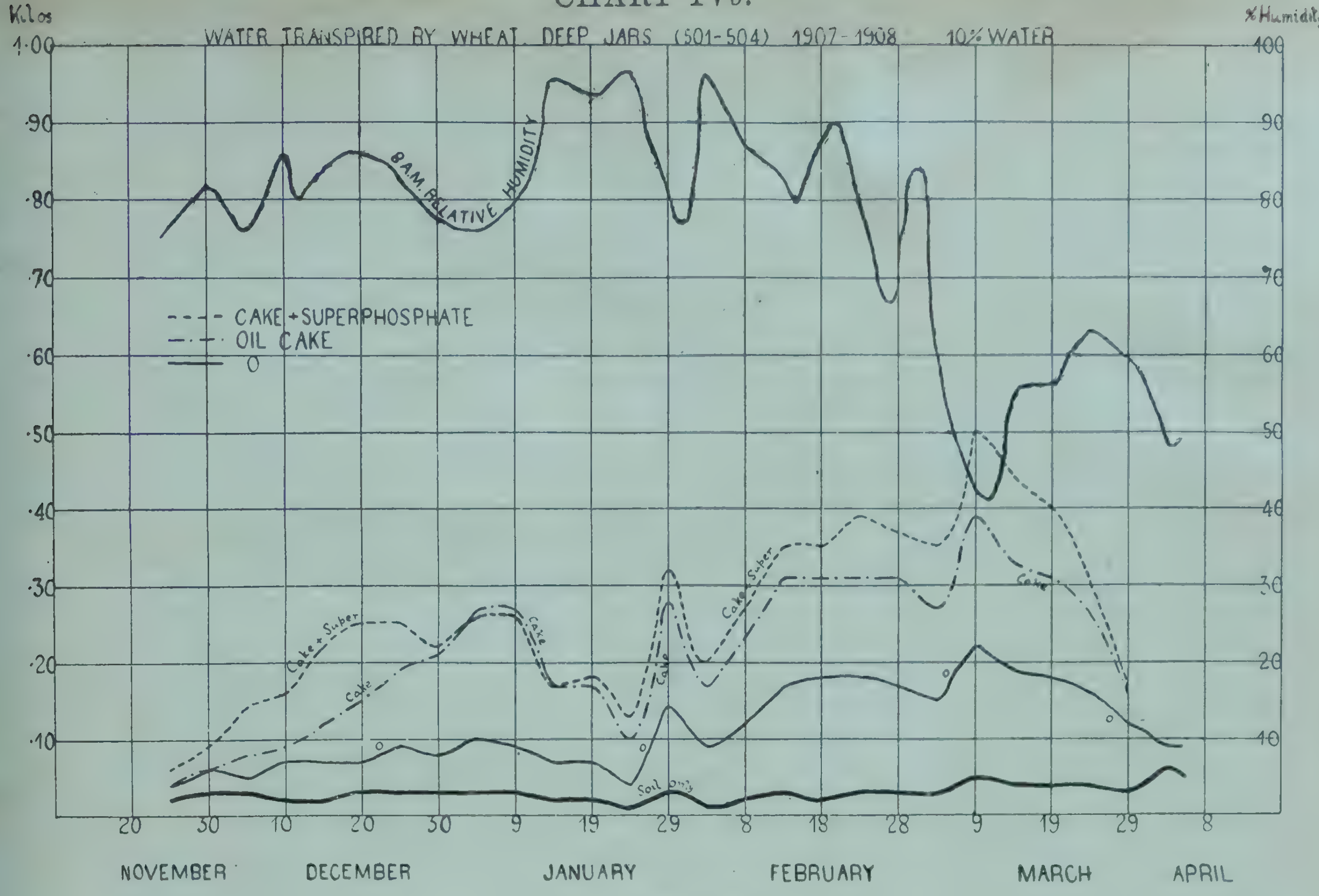
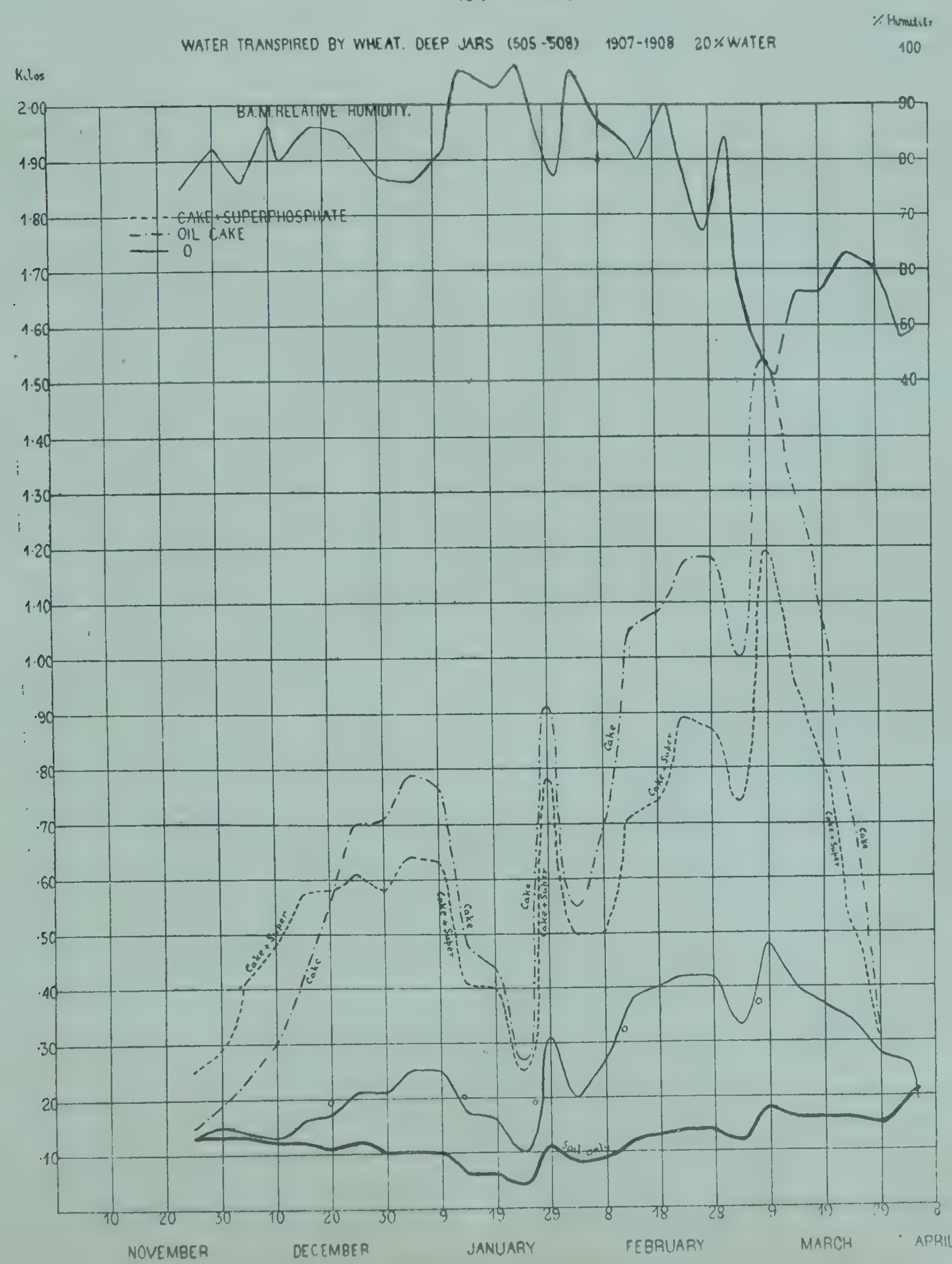

Kilos
WATER TRANSPIRED BY WHEAT. SMALL JARS (1-4) 1907-1908 10% WATER
% Hum
8 A.M. RELATIVE HUMIDITY
CAKE + SUPERPHOSPHATE
OIL CAKE
0
Cake + Super
Cake
Soil only
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
1907 - 1908
Kilos
WATER TRANSPIRED BY WHEAT. SMALL JARS (5-8) 1907-1908 20% WATER
% Hum
8 A.M. RELATIVE HUMIDITY
CAKE + SUPERPHOSPHATE
OIL CAKE
0
Cake + Super
Cake
Soil only
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
1907 - 1908

CHART IVb.



Kilos
% Humidity
WATER TRANSPIRED BY WHEAT. DEEP JARS (501-504) 1907-1908 10% WATER
1·00
·90
·80
·70
·60
·50
·40
·30
·20
·10
100
90
80
70
60
50
40
30
20
10
8 A.M. RELATIVE HUMIDITY
CAKE + SUPERPHOSPHATE
OIL CAKE
0
Cake + Super
Cake
Soil only
20
30
10
20
30
9
19
29
8
18
28
9
19
29
8
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
1907 - 1908



WATER TRANSPIRED BY WHEAT. DEEP JARS (505-508) 1907-1908 20% WATER
% Humidity
100
Kilos
2·00
1·90
1·80
1·70
1·60
1·50
1·40
1·30
1·20
1·10
1·00
·90
·80
·70
·60
·50
·40
·30
·20
·10
90
80
70
60
50
40
8 A.M. RELATIVE HUMIDITY.
CAKE + SUPERPHOSPHATE
OIL CAKE
0
Cake + Super
Cake
Soil only
10
20
30
10
20
30
9
19
29
8
18
28
9
19
29
8
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL

STATEMENT V.

Triticum sat. (Wheat) 1908-09.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of Sowing.	Date of Harvest.	Dry crop. Seed. Grms.	Dry crop. Total. Grms.	Water transpired. Kilos.	Ratio.
	A = 9″ diam. × 12″ deep.	About 14 kilos. of Pusa soil.	20		Blank	jars			(8·49)	
115			20	Nil	5-11-08	23-3-09	4·09	17·02	14·43	848
116			20	Nil	5-11-08	23-3-09	4·56	16·81	14·83	882
117			20	N	5-11-08	23-3-09	3·23	17·80	15·24	856
118			20	N	5-11-08	23-3-09	4·08	15·77	11·19	709
119			20	N + P	5-11-08	23-3-09	20·06	64·92	34·82	536
120			20	N + P	5-11-08	23-3-09	18·72	62·05	29·73	479

N = $Ca(NO_3)_2$ = ·005 grm. N ; P = superphosphate = ·01 grm. soluble P_2O_5 per 100 grms. soil.

CHART V.

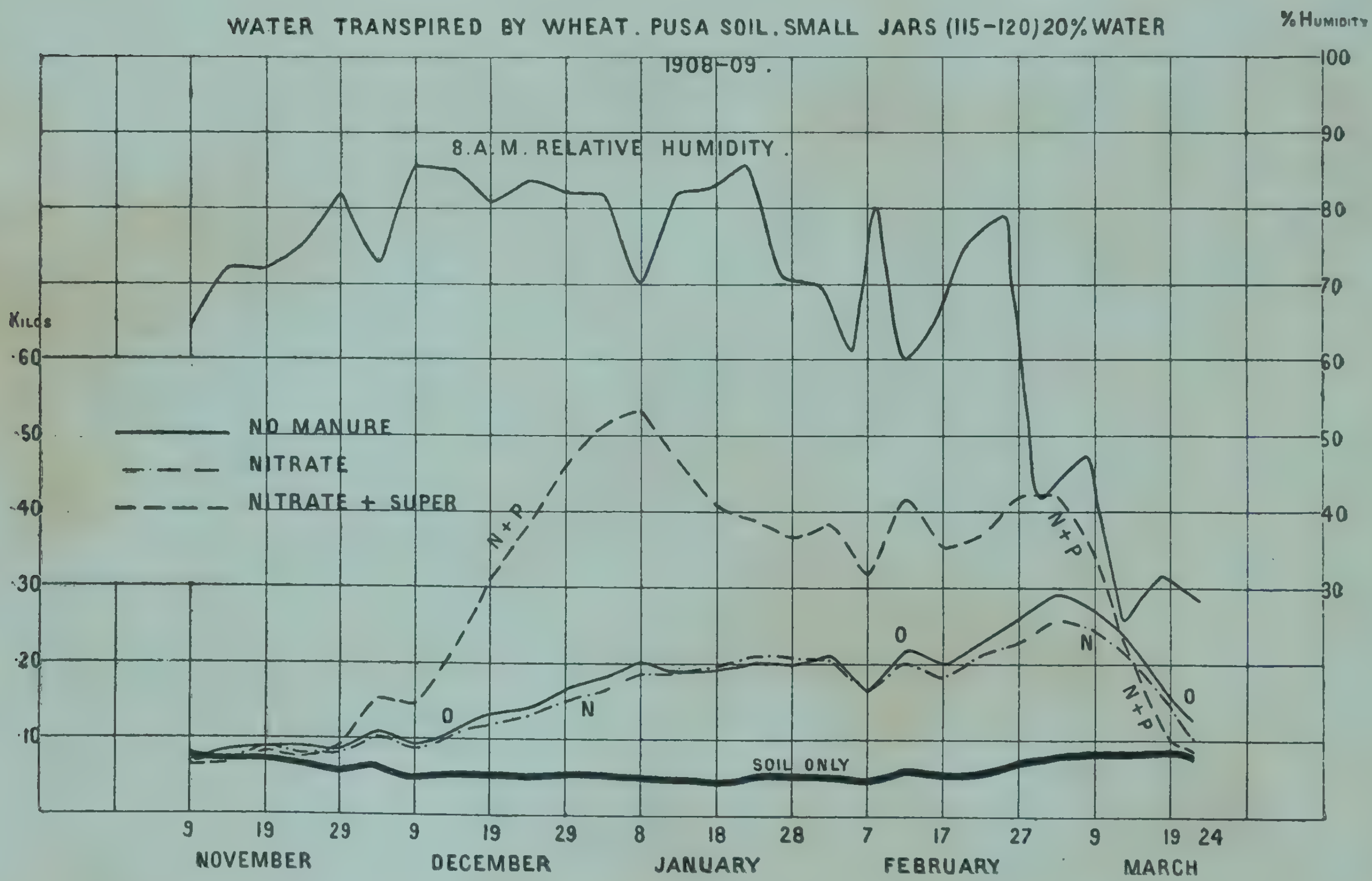
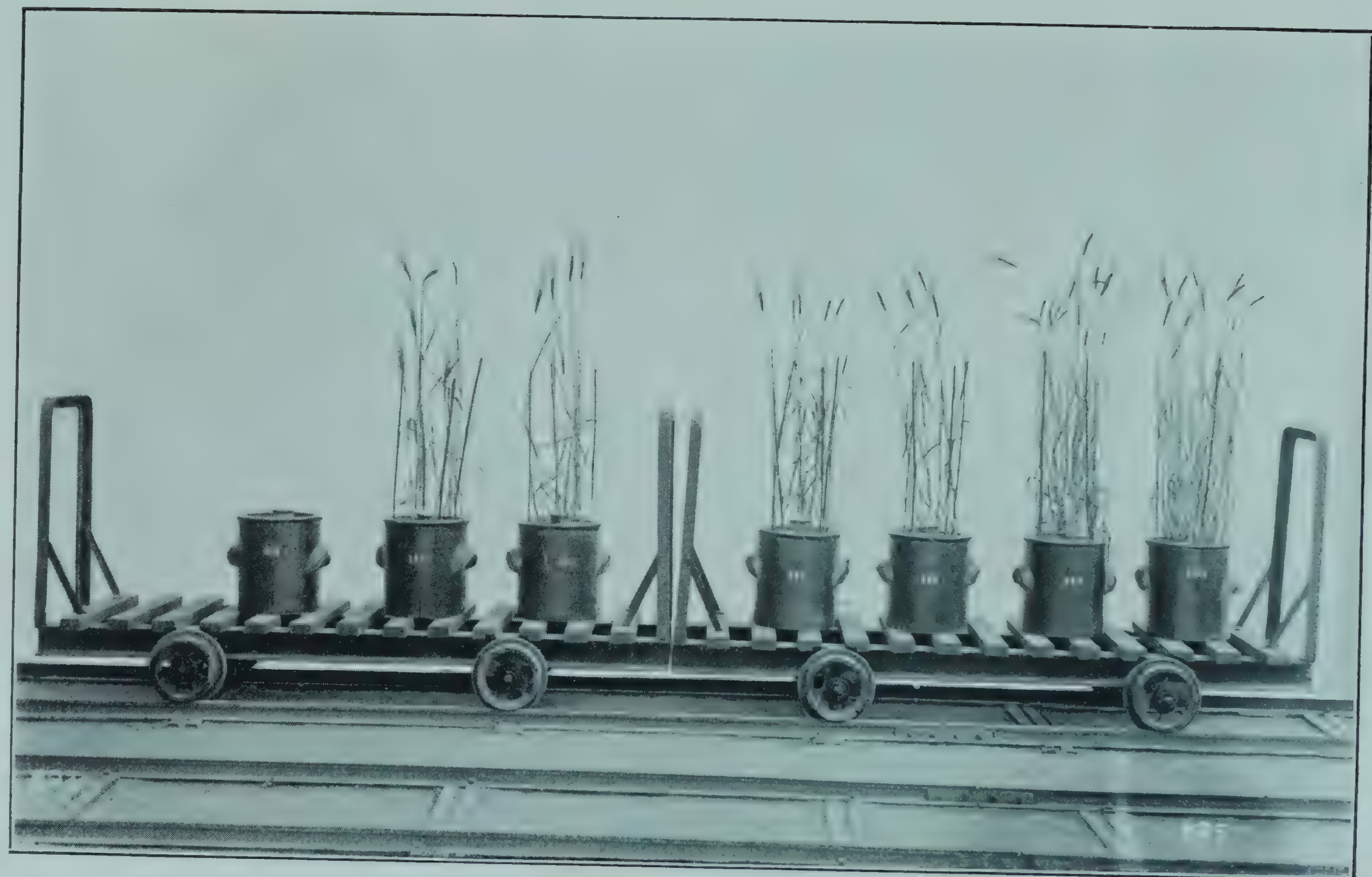


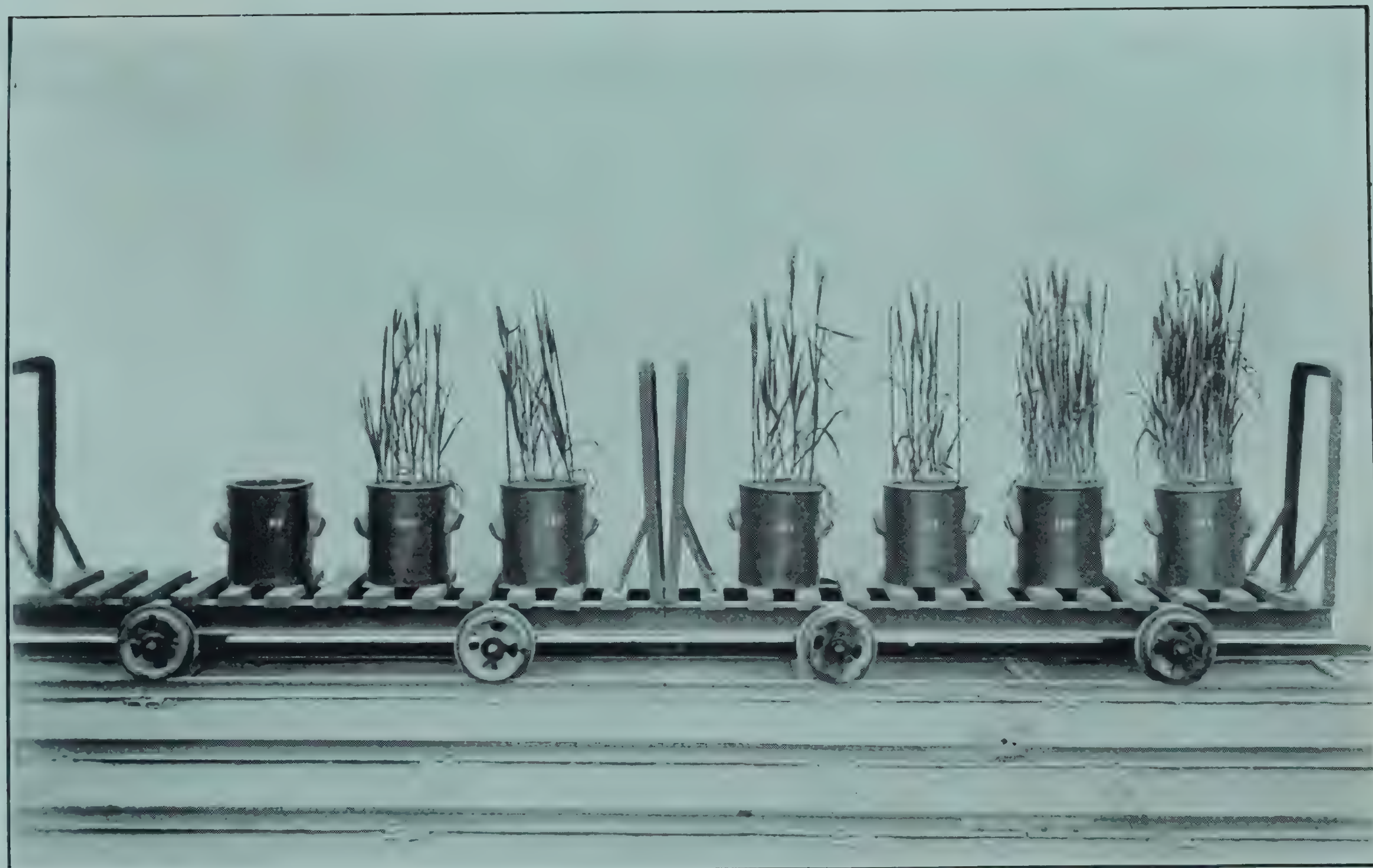
PLATE V.



WHEAT, 1908-9.

115, 116. No manure.
117, 118. Nitrate only.
119, 120. Nitrate and Superphosphate.

PLATE VI.



BARLEY, 1908-9.

109, 110. No manure.
111, 112. Nitrate only.
113, 114. Nitrate and Superphosphate.

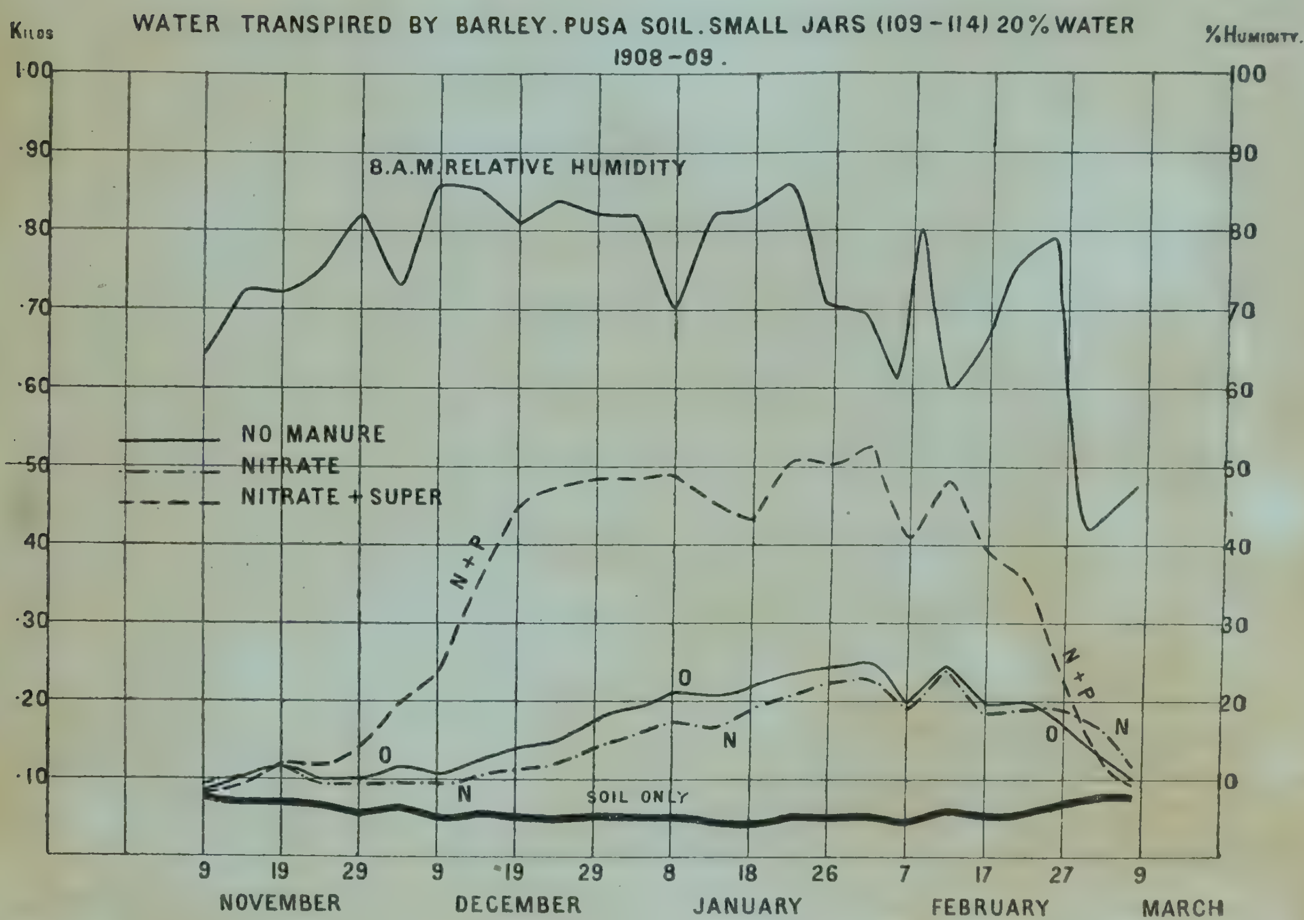
STATEMENT VI.

HORDEUM VULG. (BARLEY) 1908-09.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of Sowing.	Date of Harvest.	Dry crop. Seed. Grms.	Dry crop. Total. Grms.	Water transpired. Kilos.	Ratio.
×	A = 9″ diam. × 12″ deep.	About 14 kilos of Pusa soil.	20		Blank jars		...	...	(7·09)	...
109			20	Nil	2-11-08	8-3-09	9·5	19·9	13·52	679
110			20	Nil	2-11-08	8-3-09	9·5	19·2	12·97	676
111			20	N	2-11-08	8-3-09	8·7	28·6	12·08	422
112			20	N	2-11-08	8-3-09	7·5	26·0	11·32	435
113			20	N + P	2-11-08	8-3-09	29·9	61·1	31·58	517
114			20	N + P	2-11-08	8-3-09	34·8	80·8	36·07	446

N = $Ca(NO_3)_2$ = ·005 grm. N; P = superphosphate = ·01 grm. soluble P_2O_5 per 100 grms. soil.

CHART VI.



STATEMENT VII.

Avena sat. (Oats) 1908-09.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of Sowing.	Date of Harvest.	Dry crop. Seed. Grms.	Dry crop. Total. Grms.	Water transpired. Kilos.	Ratio.
×	A = 9″ diam. 12″ deep.	About 14 kilos of Pusa soil.	20		Blank jars		..	...	(8·04)	...
83			20	Nil	21 10 08	8 3 09	2·65	5·66	6·32	1117
84			20		21 10 08	8 3 09	5·20	10·98	6·91	629
85			20	N	5 11 08	8 3 09	5·11	11·74	10·23	871
86			20		5 11 08	8 3 09	5·30	12·20	9·54	782
87			20	N + P	21 10 08	8 3 09	22·88	52·01	31·83	612
88			20		21 10 08	8 3 09	30·65	59·58	29·21	490

N = $Ca(NO_3)_2$ = ·005 grm. N ; P = superphosphate = ·01 grm. soluble P_2O_5 per 100 grms. soil.

CHART VII.

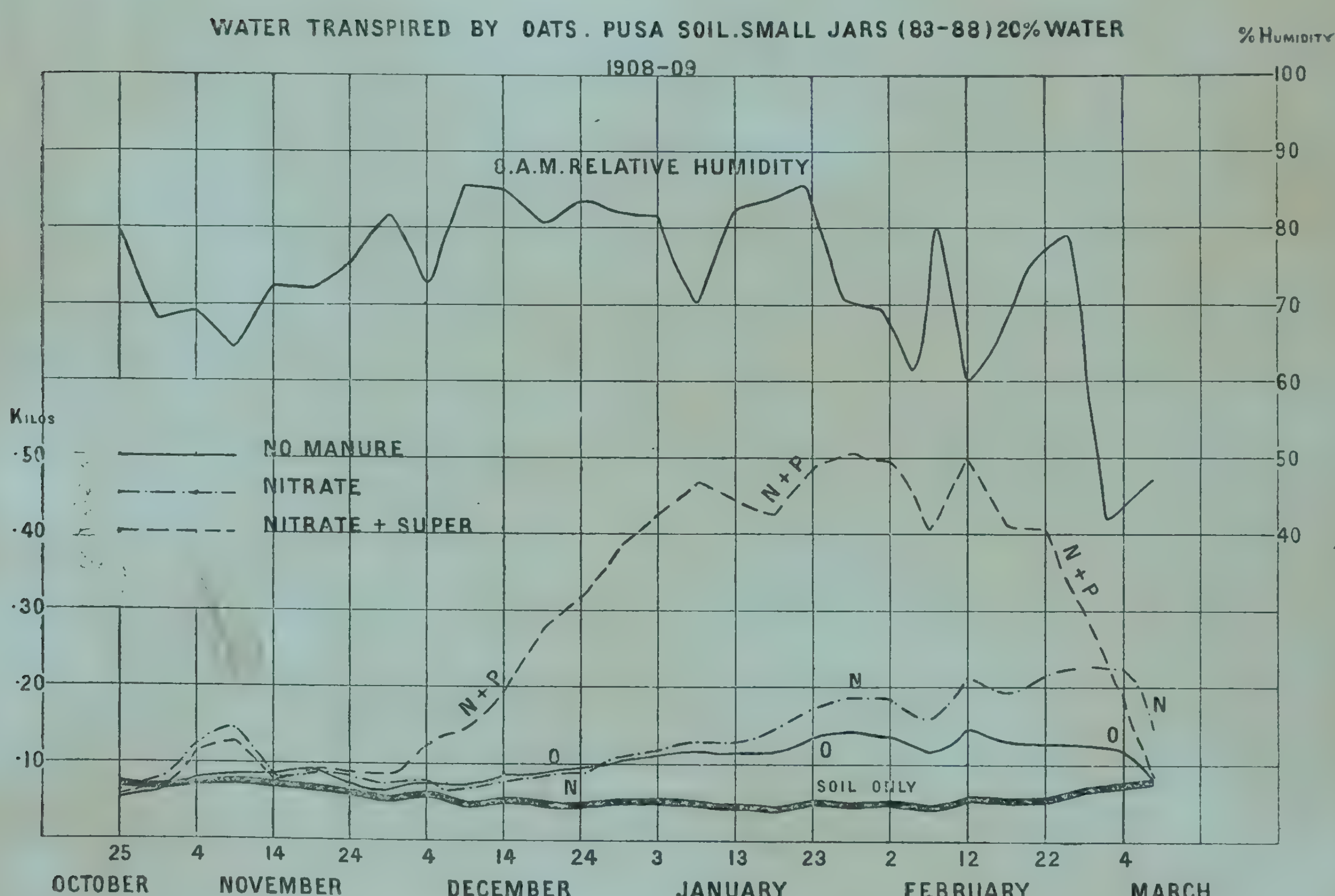
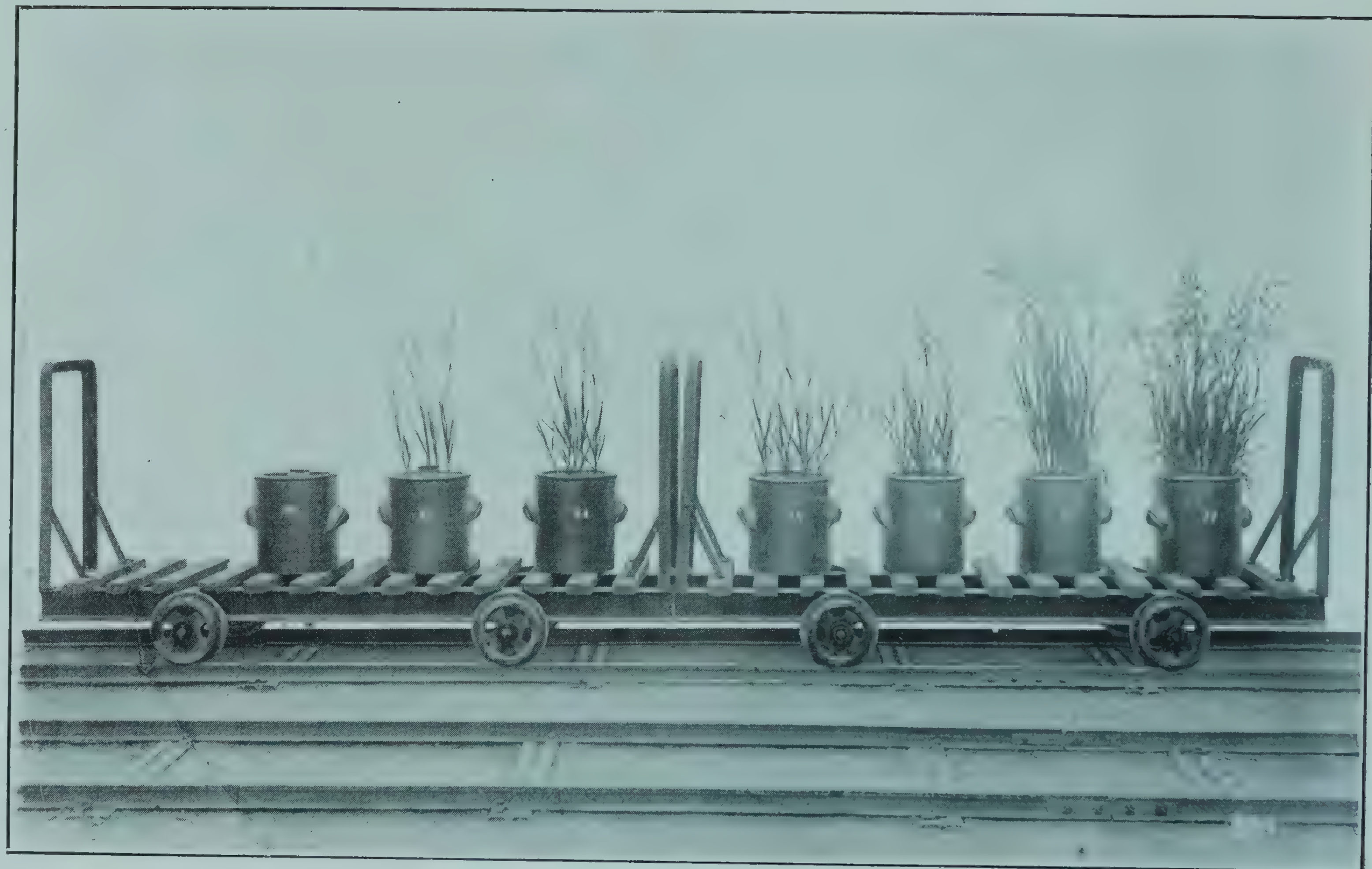


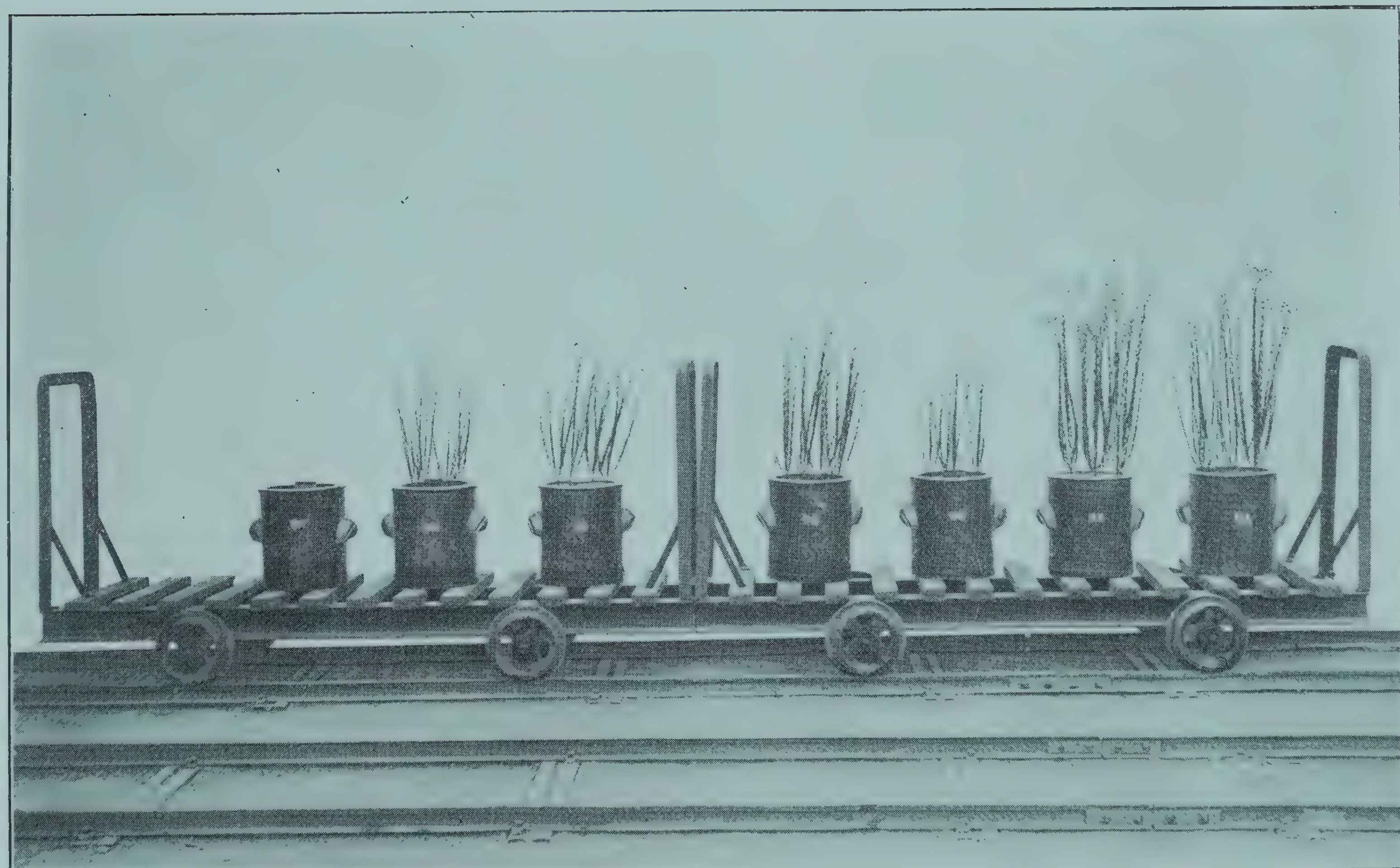
PLATE VII.



OATS, 1908-9.

83, 84. No manure.
85, 86. Nitrate only.
87, 88. Nitrate and Phosphate.

PLATE VIII.



LINSEED, 1908-9.

90, 91. No manure.
92, 93. Nitrate only.
94, 95. Nitrate and Superphosphate.

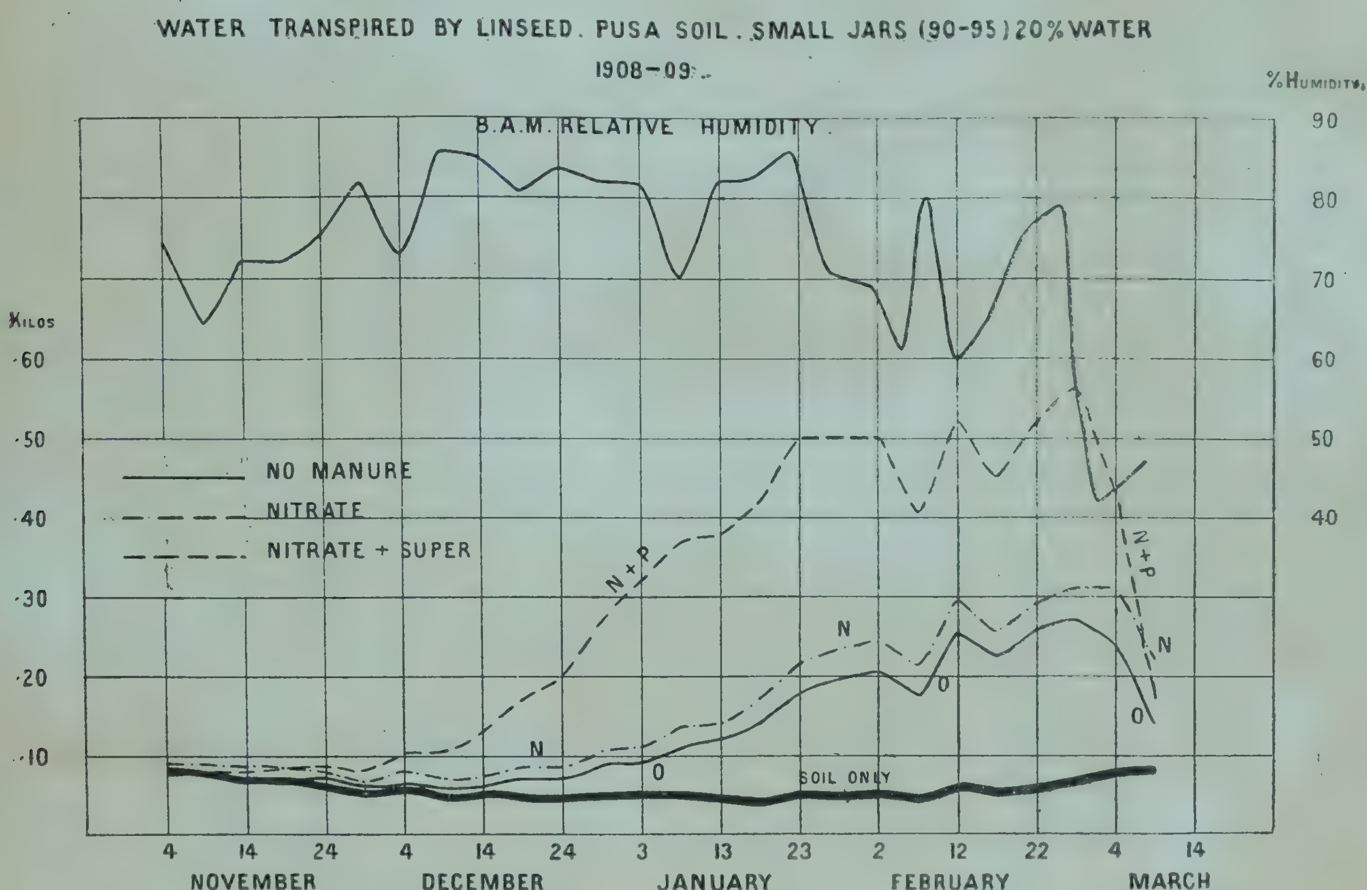
STATEMENT VIII.

GUIZOTIA ABYSS. (LINSEED) 1908-09.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of Sowing.	Date of Harvest.	Dry crop. Seed. Grms.	Dry crop. Total. Grms.	Water transpired. Kilos.	Ratio.
×	×		20		Blank jars		...	...	(7·35)	...
·90	A = 9″ diam. 12″ deep.	About 14 kilos of Pusa soil.	20	Nil	2 11 08	9 3 09	1·91	7·18	8·84	1231
91			20	Nil	2 11 08	9 3 09	2·47	11·17	10·66	954
·92			20	N	2 11 08	9 3 09	3·92	15·58	17·13	1099
93			20	N	2 11 08	9 3 09	2·00	7·35	9·53	1297
·94			20	N + P	2 11 08	9 3 09	11·68	35·78	34·27	957
·95			20	N + P	2 11 08	9 3 09	6·99	24·83	25·90	1043

N = $Ca(NO_3)_2$ = ·005 grm. N ; P = superphosphate = ·01 grm. soluble P_2O_5 per 100 grms. soil.

CHART VIII.



STATEMENT IX.

Brassica campestris (Sarson) 1908-09.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of Sowing.	Date of Harvest.	Dry crop. Seed. Grms.	Dry crop. Total. Grms.	Water transpired. Kilos.	Ratio.
×	×	About 14 kilos of Pusa soil.	20		Blank jars		..	...	7·00 / 5·93	...
76	A = 9″ diam. × 12″ deep.		20	Nil	20-10-08	23-1-09	1·65	5·69	4·10	719
77			20		20-10 08	23-1-09	1·93	6·07	4·60	754
78			20	N	20-10-08	23-1-09	4·36	14·05	12·52	888
79			20		20-10-08	23-1-09	6·88	19·81	14·82	748
80			20	N + P	20-10-08	3-2-09	7·06	23·94	15·40	644
81			20		20-10-08	3-2-09	16·43	55·88	33·82	605

N = $Ca(NO_3)_2$ = ·005 grm. N ; P = superphosphate = ·01 grm. soluble P_2O_5 per 100 grms. soil.

CHART IX.

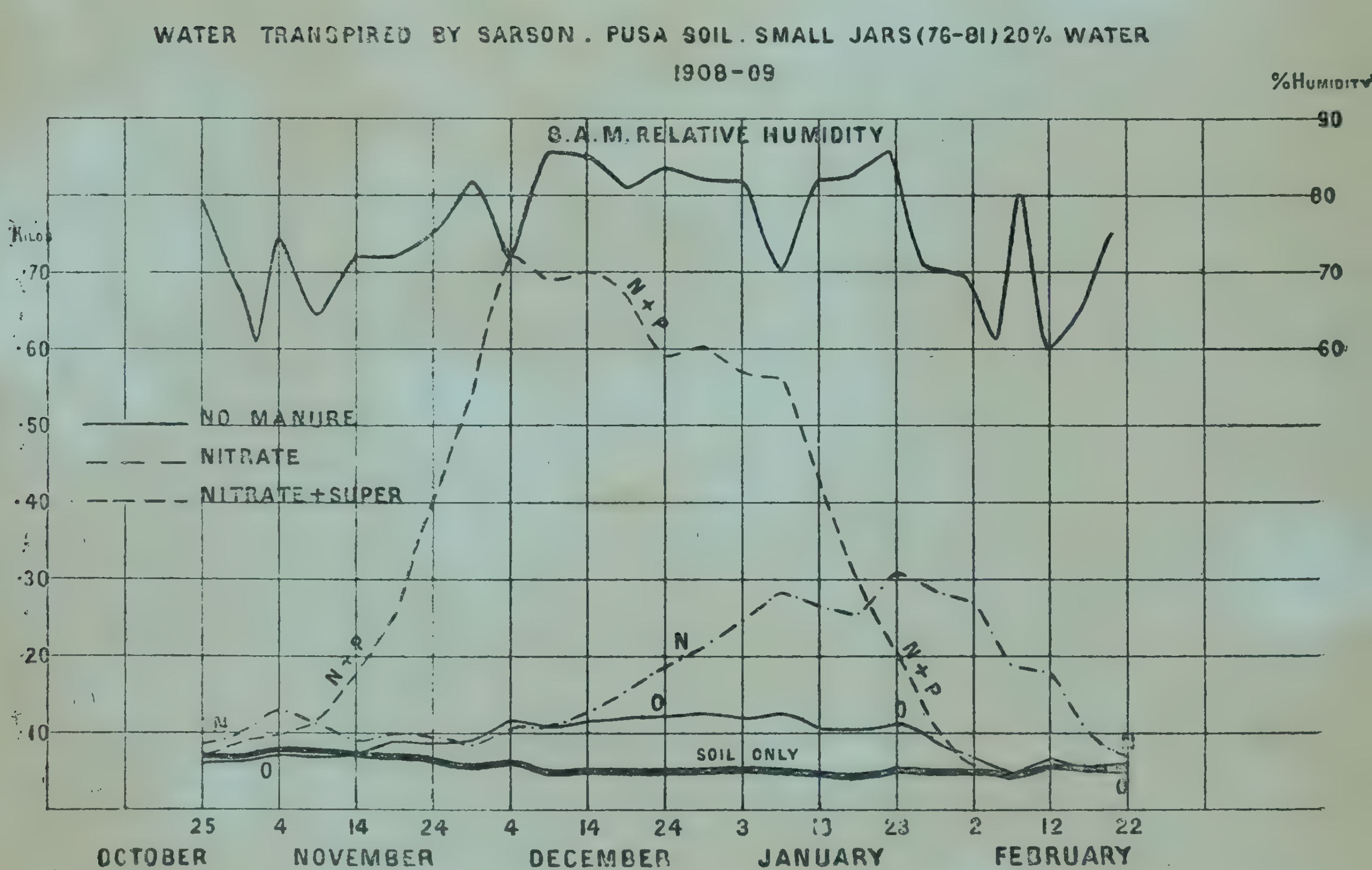
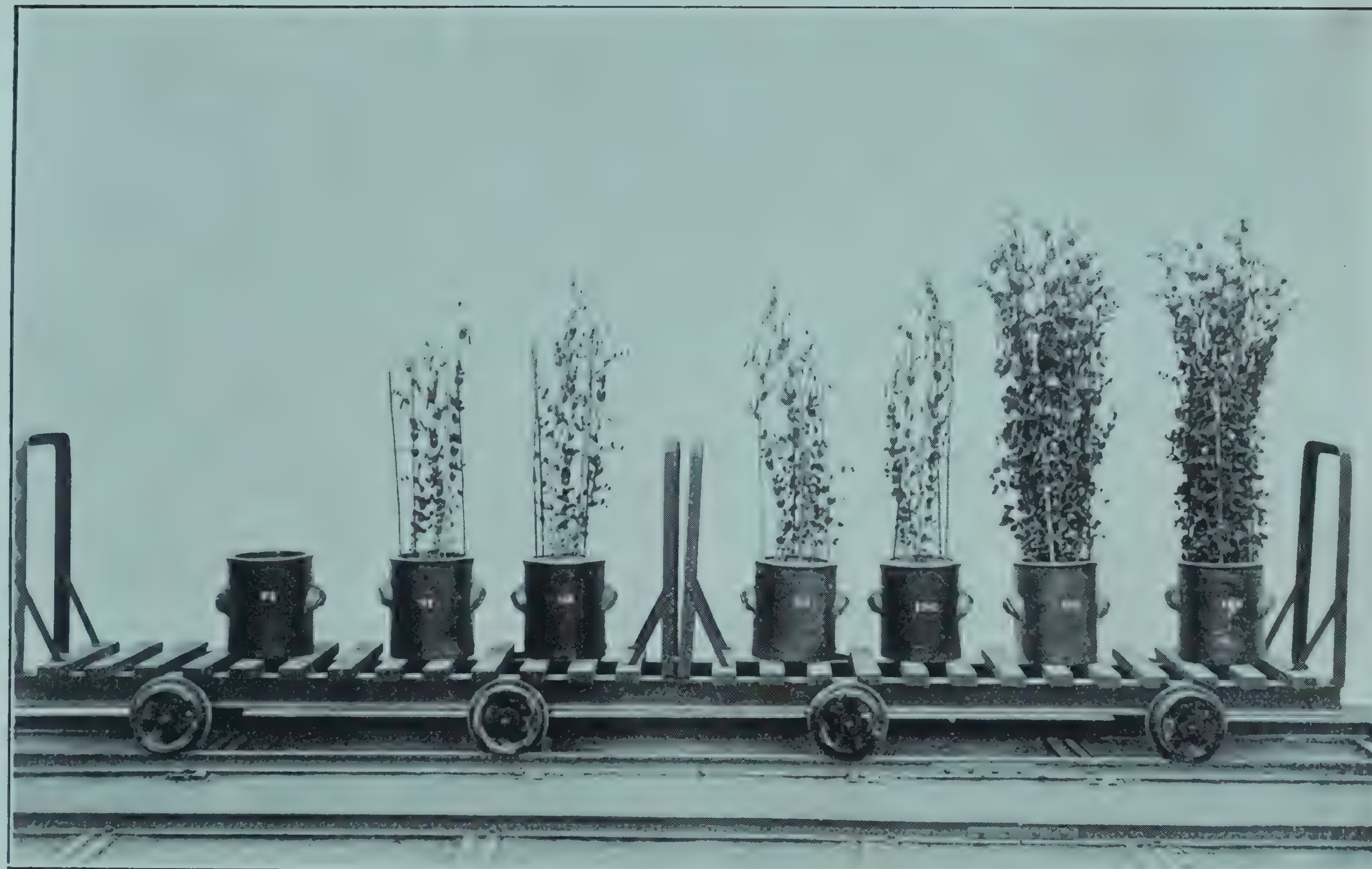


PLATE X.



PEAS, 1908-9.

97, 98. No manure.
99, 100. Nitrate only.
101, 102. Nitrate and Superphosphate.

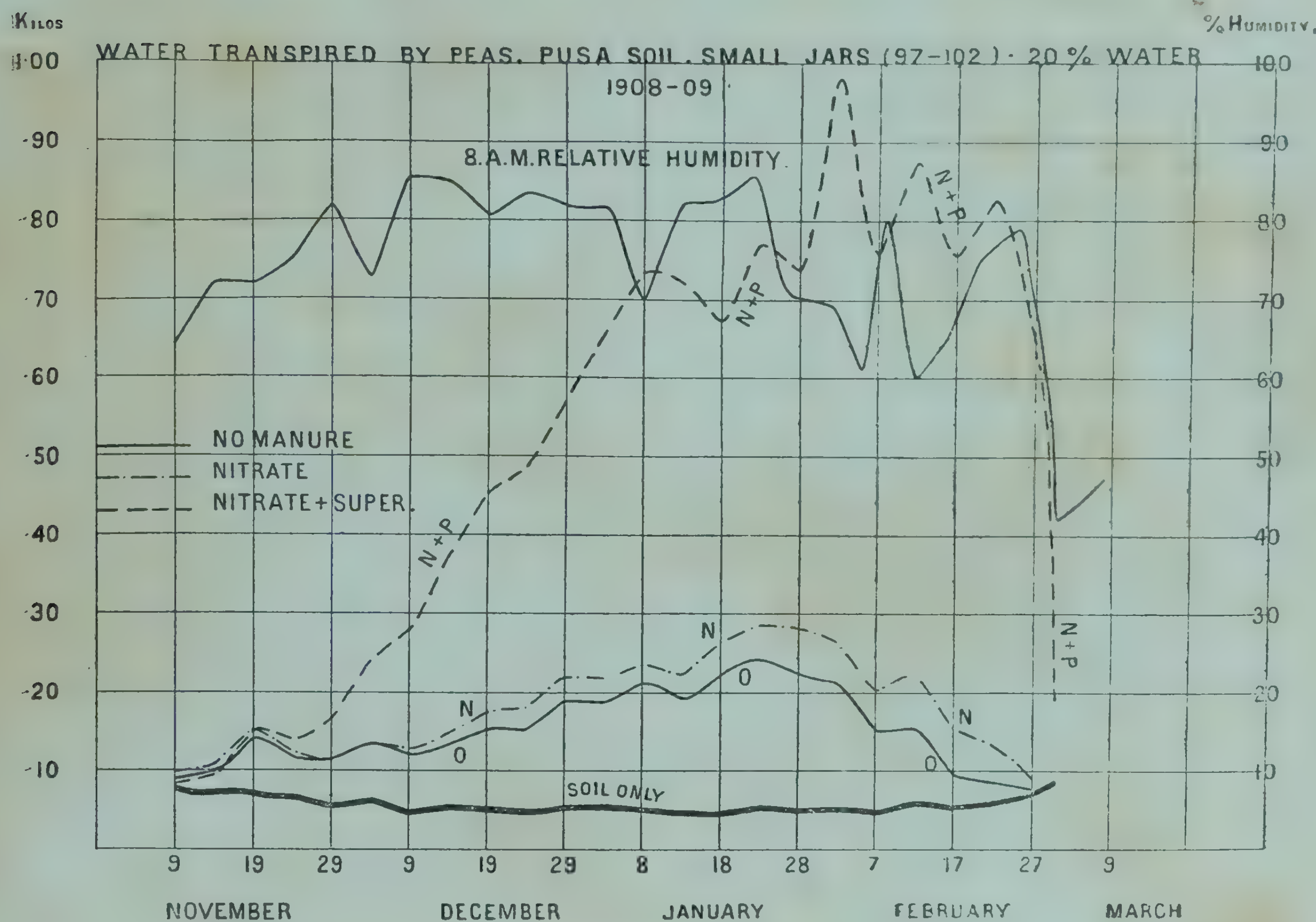
STATEMENT X.

PISUM SAT. (PEAS) 1908-09.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of Sowing.	Date of Harvest.	Dry crop. Seed. Grms.	Dry crop. Total. Grms.	Water transpired. Kilos.	Ratio.
×	A = 9″ diam. × 12″ deep.	About 14 kilos of Pusa soil.	20		Blank jars		...	...	(6·00)	...
97			20	Nil ...	2-11-08	1-3-09	5·5	11·6	11·29	973
98			20		2-11-08	1-3-09	7·2	15·8	11·03	698
99			20	N ...	2-11-08	1-3-09	8·5	20·1	14·94	743
100			20		2-11-08	1-3-09	6·8	16·6	13·71	826
101			20	N+P ...	2-11-08	3-3-09	47·9	115·7	52·35	453
102			20		2-11-08	3-3-09	36·2	94·9	57·72	608

N = $Ca(NO_3)_2$ = ·005 grm. N; P = superphosphate = ·01 grm. soluble P_2O_5 per 100 grms. soil.

CHART X.



STATEMENT XI.

Cicer arietinum (Gram) 1908-09.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of Sowing.	Date of Harvest.	Dry crop. Seed. Grms.	Dry crop. Total. Grms.	Water transpired. Kilos.	Ratio.
×	A = 9″ diam. × 12″ deep.	About 14 kilos of Pusa soil.	20		Blank jars		...	...	(7·09)	...
103			20	Nil ...	2-11-08	8-3-09	2·4	7·0	10·66	1523
104			20		2-11-08	8 3-09	3·7	8·9	11·88	1335
105			20	N ...	2-11-08	8-3-09	4·7	9·9	10·40	1050
106			20		2-11-08	8-3-09	3·8	10·2	13·49	1323
107			20	N+P ...	2 11-08	8-3-09	7·2	21·1	23·78	1127
108			20		2-11-08	8-3-09	30·7	67·1	55·36	825

N = $Ca(NO_3)_2$ = ·005 grm. N ; P = superphosphate = ·01 grm. soluble P_2O_5 per 100 grms. soil.

CHART XI.

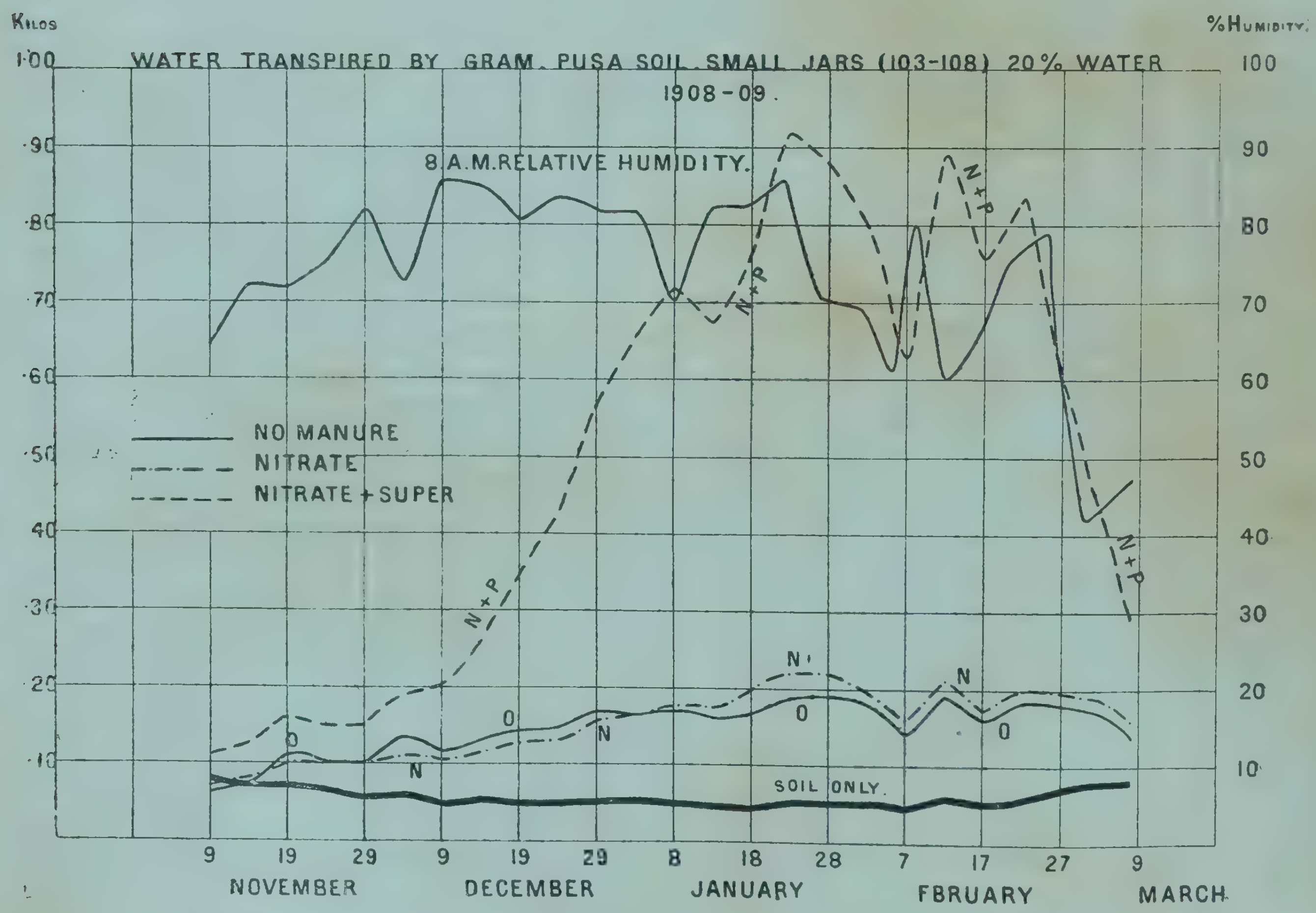
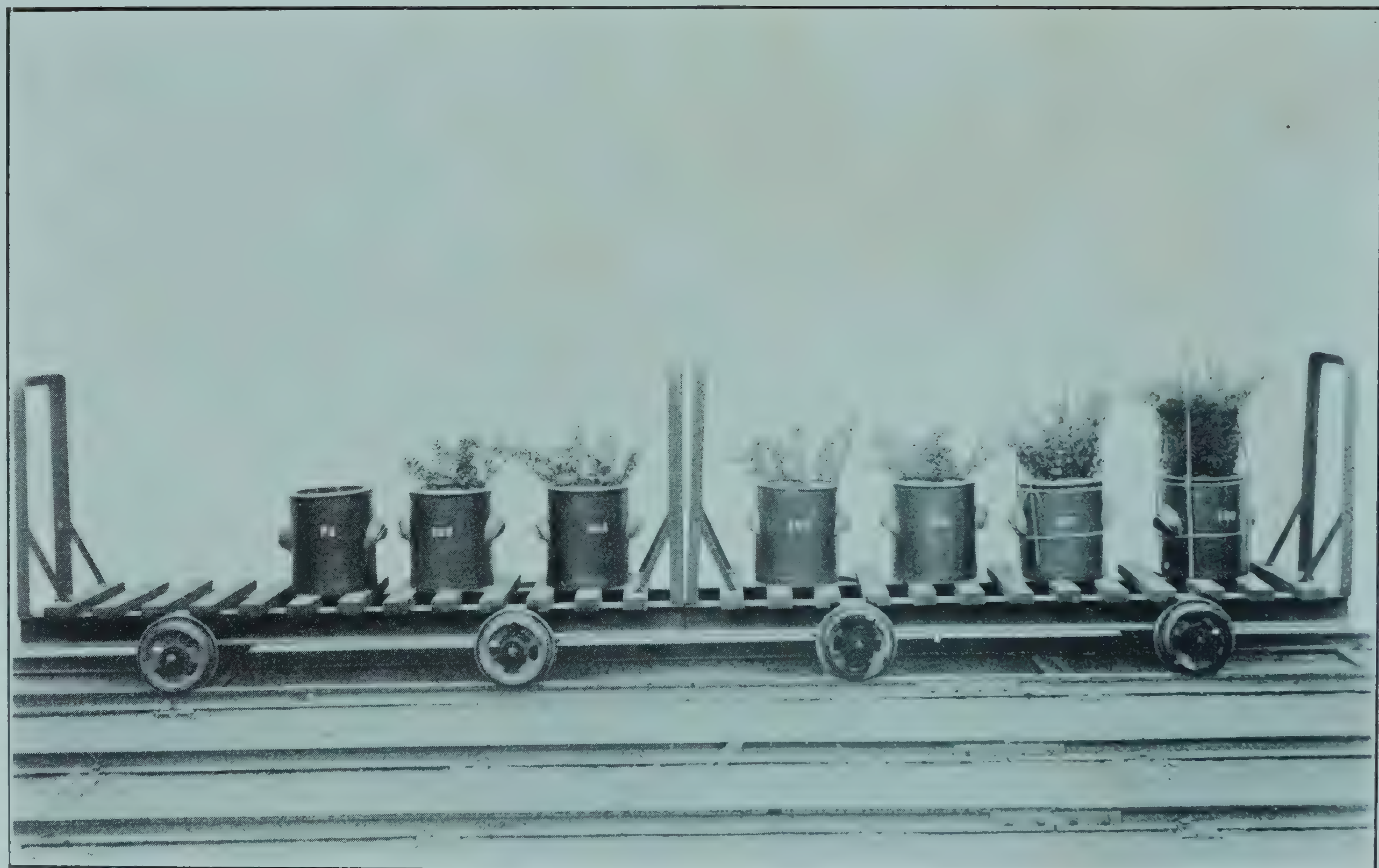


PLATE XI.



GRAM, 1908-9.

103, 104. No manure.
105, 106. Nitrate only.
107, 108. Nitrate and Superphosphate.

STATEMENT XII.

ZEA MAIS (MAIZE) 1907.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	DATE OF		DRY CROP.		Water trans-pired. Kilos.	RATIO.
					Sowing.	Harvest.	Seed. Grms.	Total. Grms.		
1	A = 9″ diam. × 12″ deep.	About 15 kilos of Pusa soil.	10	Nil	21-7-07	20-10-07	·05	11·26	5·17	459
2			10	N	21-7-07	20-10-07	Nil	20·07	8·11	404
3			10	N+P	21-7-07	20-10-07	Nil	41·41	11·90	287
4			10	N+P+K	21-7-07	20-10-07	Nil	41·23	14·21	344
5			10	Nil	Blank	jar			(2·27)	
6			15	Nil	21-7-07	20-10-07	·1	11·63	4·28	368
7			15	N	21-7-07	20-10-07	·15	28·53	10·78	377
8			15	N+P	21-7-07	20-10-07	4·9	35·10	11·34	323
9			15	N+P+K	21-7-07	20-10-07	·7	24·12	7·79	322
10			15	N+P+K	Blank	jar			(3·65)	
11			20	Nil	21-7-07	20-10-07	Nil	11·26	6·81	604
12			20	N	21-7-07	20-10-07	Nil	17·1	9·05	529
13			20	N+P	21-7-07	20-10-07	1·8	35·82	13·70	382
14			20	N+P+K	21-7-07	20-10-07	·2	51·03	17·15	336
15			20	Nil	Blank	jar	...	...	(3·73)	...

$N = Ca(NO_3)_2$ = ·005 grm. N per 100 grms. soil P = superphosphate = ·010 grm. soluble P_2O_5 and $K = K_2SO_4$ = ·005 grm. K_2O per 100 grms. soil.

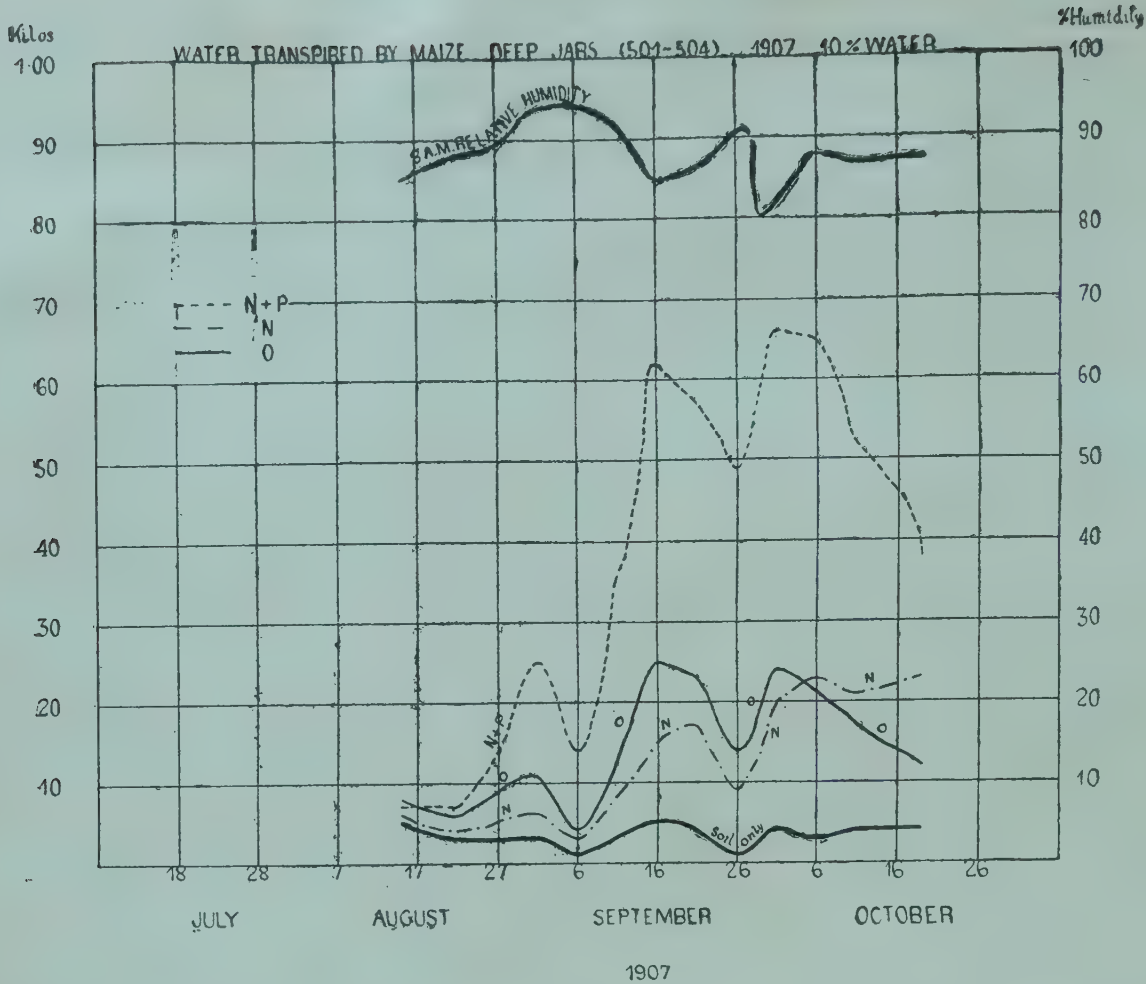
401	B = 9″ diam. × 16″ deep.	About 21 kilos of Pusa soil.	10	Nil	20-7-07	20-10-07	·40	13·0	6·52	500
402			10	N	20-7-07	20-10-07	·40	16·85	10·87	645
403			10	N + P	20-7-07	20-10-07	18·60	67·8	20·96	309
404			10	Nil	Blank	...	...	...	(4·21)	...
405			15	Nil	20-7-07	20-10-07	Nil	10·22	6·02	589
406			15	N + P	20-7-07	20-10-07	22·00	92·07	25·86	281
407			15	N + P	Blank	...	...	...	(7·54)	...
408			20	Nil	20-7-07	20-10-07	1·30	15·4	5·88	381
409			20	N	20-7-07	20-10-07	1·80	21·0	11·16	527
410			20	N + P	20-7-07	20-10-07	5·70	82·7	24·44	295
411			20	Nil	Blank	...	...	...	(9·70)	...

$N = Ca(NO_3)_2$ = ·005 grm. N ; P = superphosphate = ·01 grm. soluble P_2O_5 per 100 grms. soil.

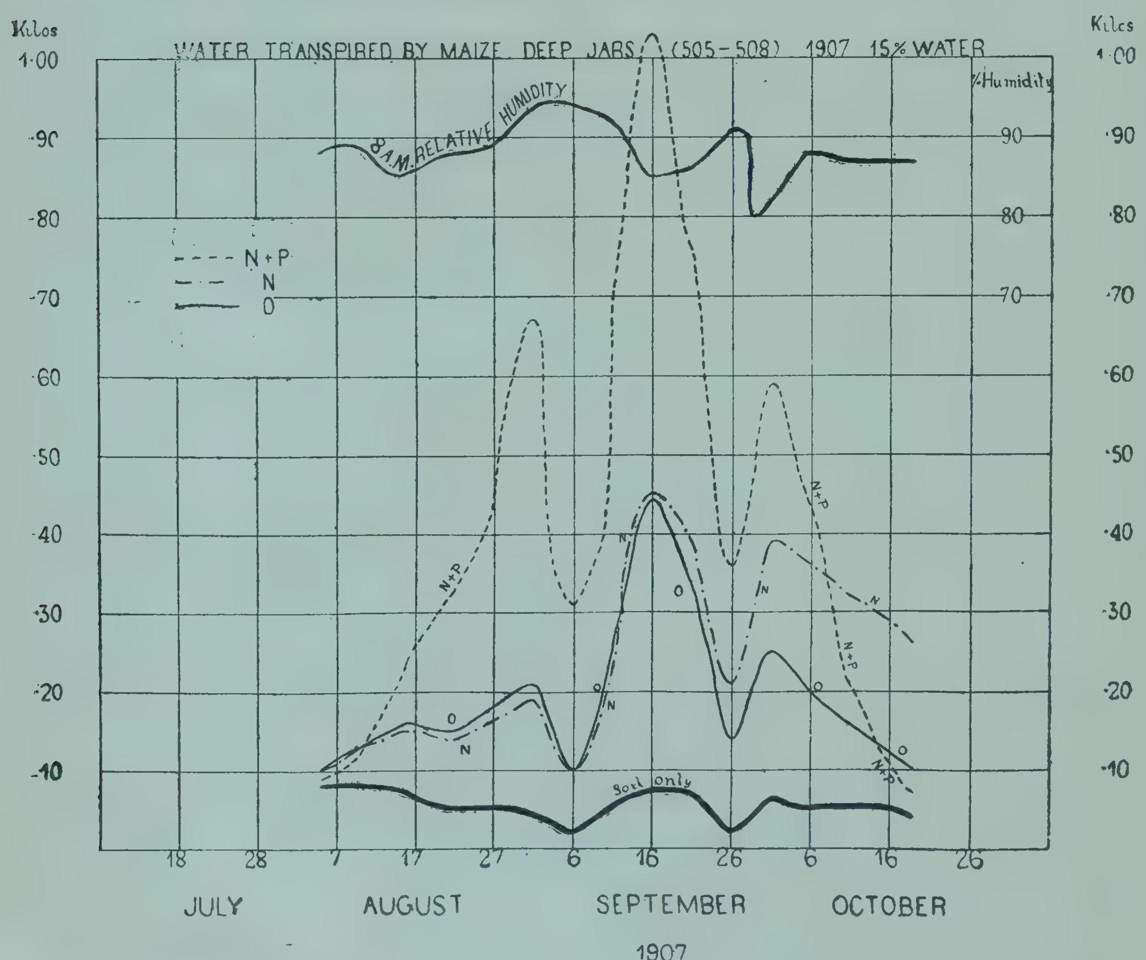
501	C = 9″ diam. × 22″ deep.	About 31 kilos of Pusa soil.	10	Nil ...	20-7-07	19-10-07	Nil	16·8	7·56	450
502			10	N ...	20-7-07	19-10-07	Nil	15·4	6·35	412
503			10	N + P ...	20-7-07	19-10-07	17·8	92·2	24·16	262
504			10	Nil ...	Blank	jar	...	...	(3·02)	...
505			15	Nil ...	20-7-07	19-10-07	4·8	26·25	11·06	421
506			15	N ..	20-7-07	19-10-07	2·2	29·07	14·68	505
507			15	N + P ...	20-7-07	19-10-07	18·5	97·80	27·97	286
508			15	N + P ...	Blank	jar	...	...	(5·73)	...
509			20	Nil ...	20-7-07	19-10-07	1·4	30·75	13·20	429
510			20	N ...	20-7-07	19-10-07	1·8	39·03	18·73	480
511			20	N + P ...	20-7-07	19-10-07	4·7	112·08	33·33	295
512			20	Nil ...	Blank	jar	...	...	(9·16)	...

$N = Ca(NO_3)_2$ = ·005 grm. N ; P = superphosphate = ·01 grm. soluble P_2O_5 per 100 grms. soil.

CHART XIIa.

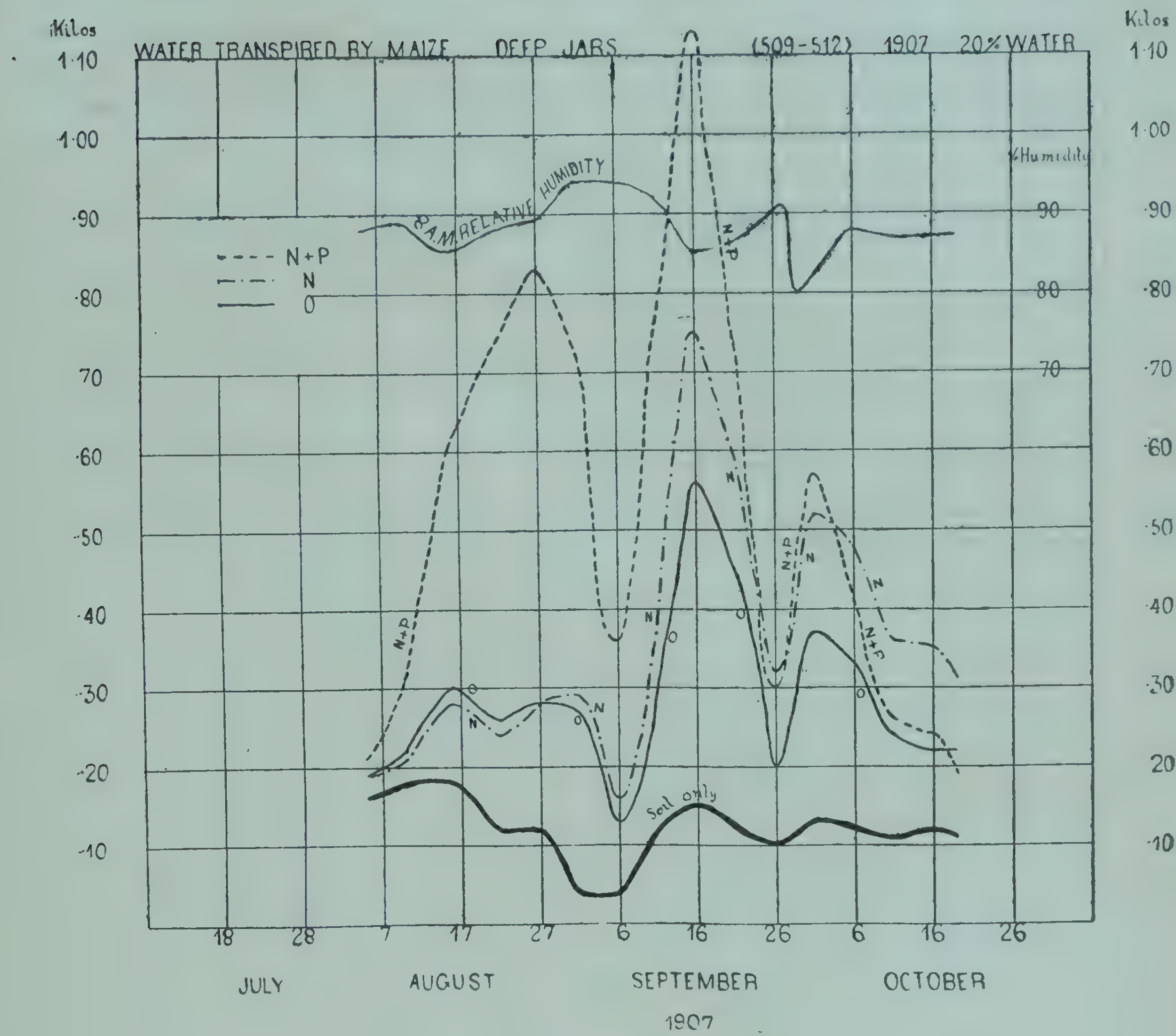


Kilos
%Humidity
WATER TRANSPIRED BY MAIZE. DEEP JARS (501-504). 1907 10% WATER
1·00
90
80
70
60
50
40
30
20
10
100
8 A.M. RELATIVE HUMIDITY
N+P
N
O
Soil only
18
28
7
17
27
6
16
26
6
16
26
JULY
AUGUST
SEPTEMBER
OCTOBER
1907



Kilos
Kilcs
WATER TRANSPIRED BY MAIZE. DEEP JARS (505-508) 1907 15% WATER
%Humidity
1·00
·90
·80
·70
·60
·50
·40
·30
·20
·10
90
80
70
8 A.M. RELATIVE HUMIDITY
N+P
N
O
Soil only
18
28
7
17
27
6
16
26
6
16
26
JULY
AUGUST
SEPTEMBER
OCTOBER
1907

CHART XIIb.



Kilos
WATER TRANSPIRED BY MAIZE. DEEP JARS. (509-512) 1907 20% WATER
Kilos
1·10
1·00
·90
·80
70
·60
·50
·40
·30
·20
·10
% Humidity
90
80
70
20
10
R.A.M. RELATIVE HUMIDITY
N+P
N
O
Soil only
18
28
7
17
27
6
16
26
6
16
26
JULY
AUGUST
SEPTEMBER
OCTOBER
1907

STATEMENT XIII.

ZEA MAIS (MAIZE) 1908.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of Sowing.	Date of Harvest.	Dry crop. Seed. Grms.	Dry crop. Total. Grms.	Water transpired. Kilos.	Ratio.
×	A = 9″ diam. × 12″ deep.	About 14 kilos of Pusa soil.	20	......	Blank jars		...	...	(7·80)	...
2			20	Nil ...	8-6-08	17-9-08	Nil ...	31·4	14·02	446
3			20		8-6-08	17-9-08	Nil ...	31·5	12·51	397
4			20	N ...	8-6-08	17-9-08	Nil ...	30·4	14·58	480
5			20		8-6-08	17-9-08	·2	32·8	13·01	397
6			20	N+P ...	8-6-08	17-9-08	Nil ...	49·9	22·41	444
7			20		8-7-08	17-9-08	·5	65·0	27·41	422

N = $Ca(NO_3)_2$ = ·005 grm. N; P = superphosphate = ·01 grm. soluble P_2O_5 per 100 grms. soil.

CHART XIII.

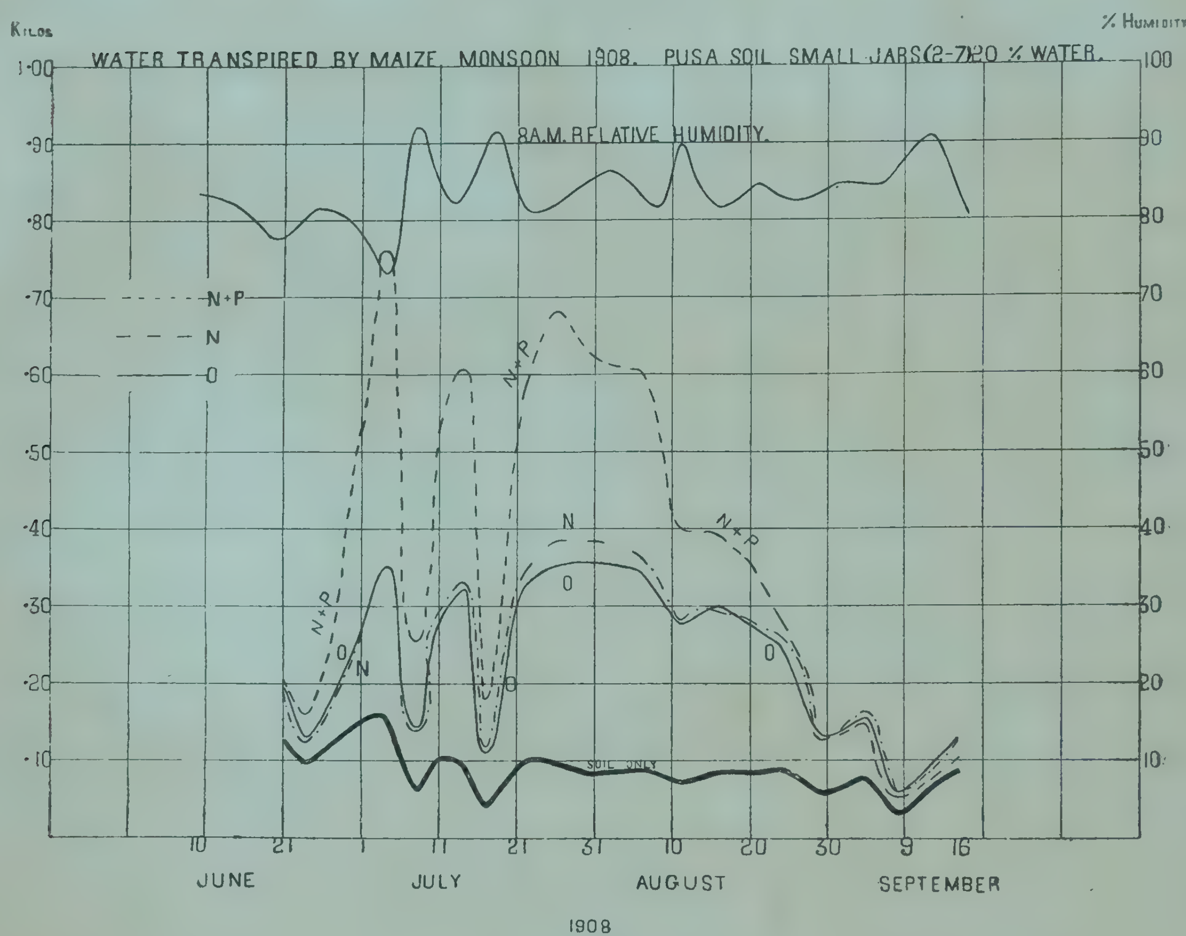
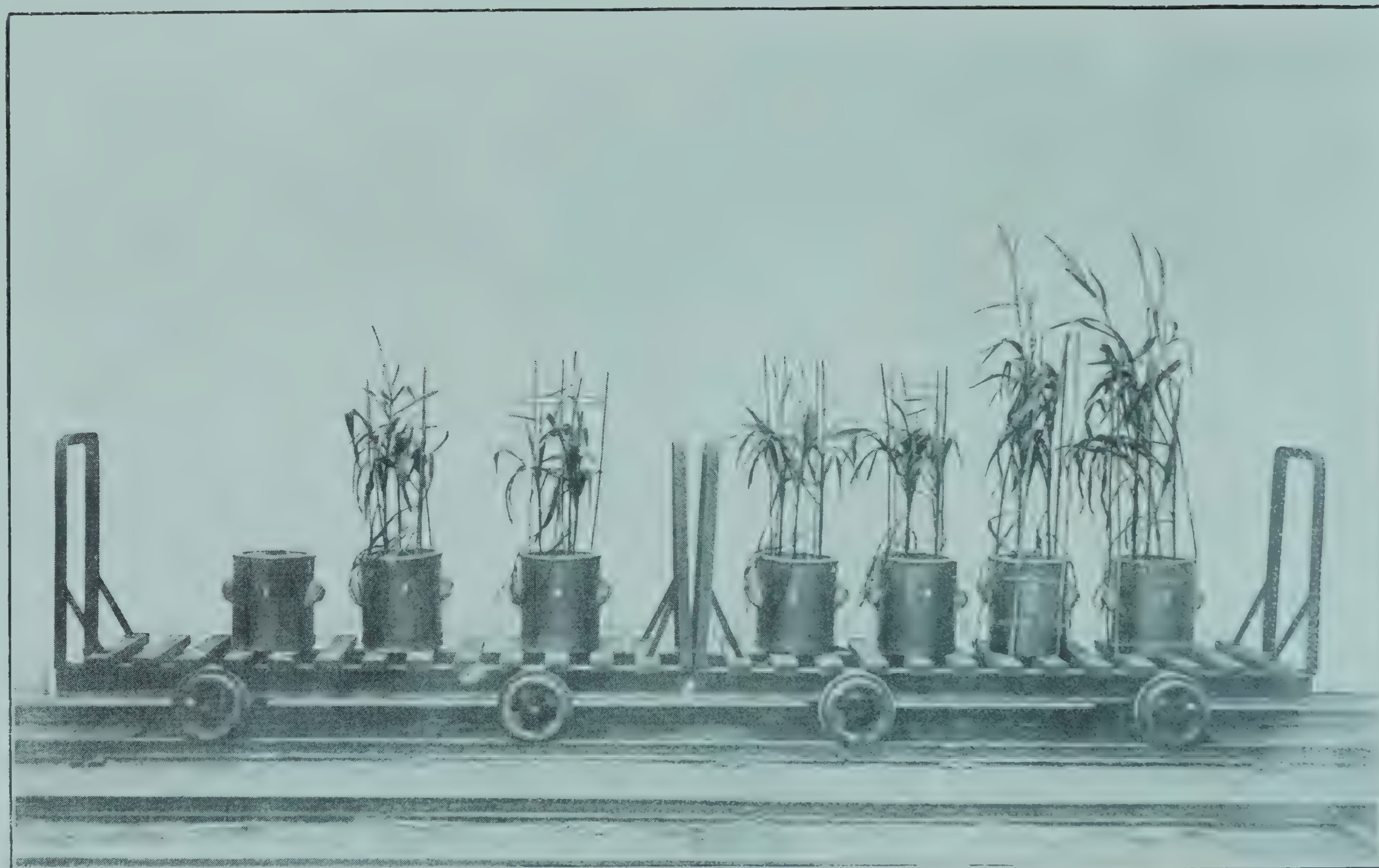


PLATE XIII.



MAIZE, 1908.

2, 3. No manure.
4, 5. Nitrate only.
6, 7. Nitrate and Superphosphate.

PLATE XIV.

JUAR, 1908.

43, 44. No manure.
45, 46. Nitrate only.
47, 48. Nitrate and Superphosphate.

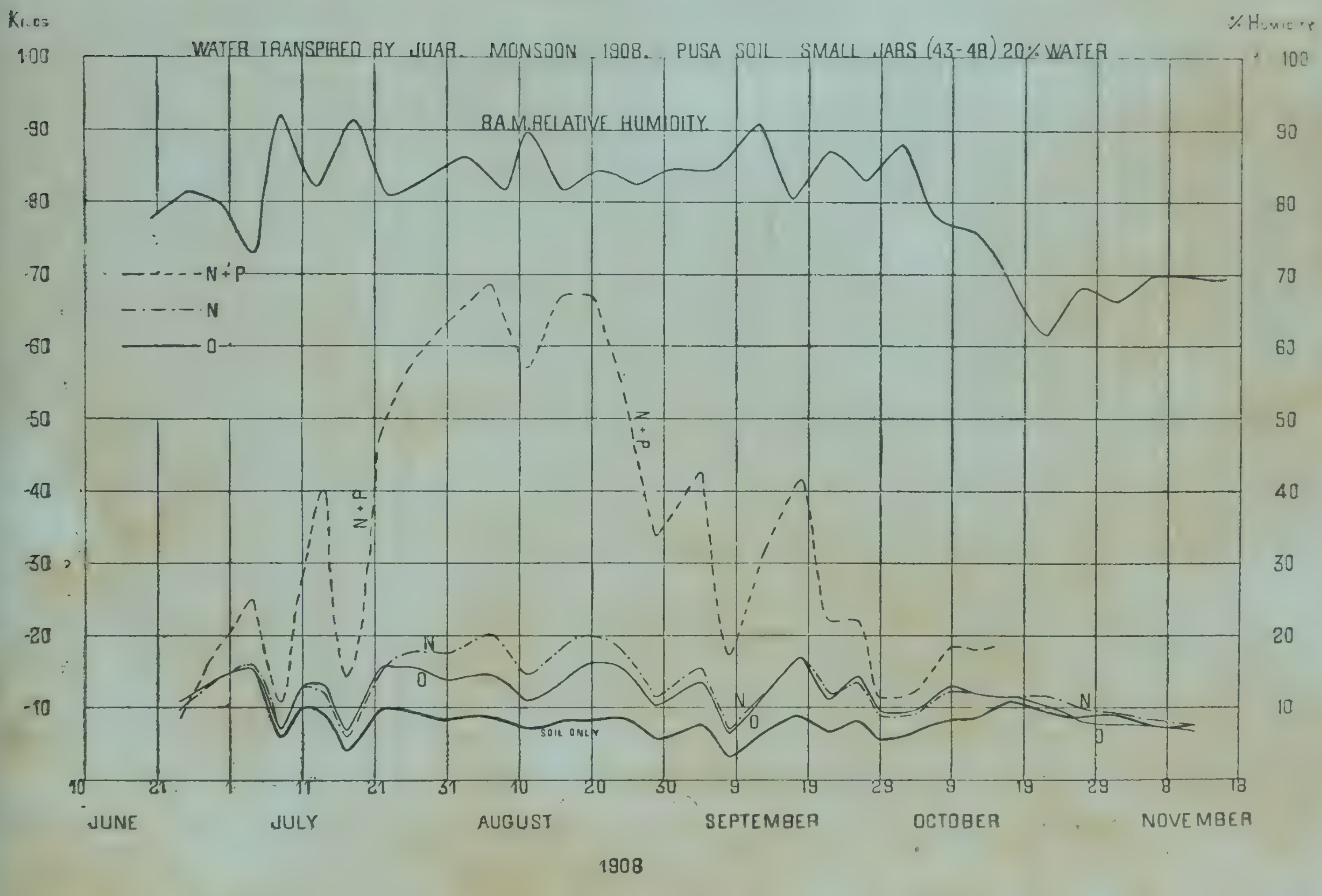
STATEMENT XIV.

ANDROPOGON SORGHUM (JUAR) 1908.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of		Dry crop.		Water transpired. Kilos.	Ratio.
					Sowing.	Harvest.	Seed. Grms.	Total. Grms.		
×	A = 9" diam. × 12" deep.	About 14 kilos of Pusa soil.	20	...	Blank jars		...	...	(11·94)	...
43			20	Nil ...	15-6-08	13-11-08	2·1	12·6	3·40	270
44			20		15-6-08	13-11 08	2·4	14·8	6 67	451
45			20	N ...	15-6 08	13-11-08	1·4	12·7	6·21	489
46			20		15 6 08	13-11-08	1·8	20·3	7·11	350
47			20	N + P ...	15-6-08	16-10-08	5·4	74·3	36·09	486
48			20		15-6-08	16-10-08	9·1	72·5	28·10	388

N = $Ca(NO_3)_2$ = ·005 grm. N ; P = superphosphate = ·01 grm. soluble P_2O_5 per 100 grms. soil.

CHART XIV.



STATEMENT XV.

ORYZA SATIVA (RICE) 1908.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of Sowing.	Date of Harvest.	Dry crop. Seed. Grms.	Dry crop. Total. Grms.	Water transpired. Kilos.	Ratio.
×	A = 9" diam. × 12" deep.	About 14 kilos of Pusa soil.	20	......	Blank jars		...	...	(15·00)	...
23			20	Nil ...	10-6-08	18-12-08	5·4	17·8	20·15	1132
24			20		10-6-08	18-12-08	4·8	22·5	18·45	820
25			20	N ...	10-6-08	18-12-08	6·9	23·7	25·24	1065
26			20		10-6-08	18-12-08	3·6	24·7	20·62	835
27			20	N+P ...	10-6-08	18-12-08	13·5	43·1	35·48	823
28			20		10-6-08	18-12-08	16·6	62·2	49·64	798

N = $Ca(NO_3)_2$ = ·005 grm. N ; P = superphosphate = ·01 grm. soluble P_2O_5 per 100 grms. soil.

CHART XV.

WATER TRANSPIRED BY RICE MOSOON 1908 PUSA SOIL SMALL JARS (23-28) 20% WATER

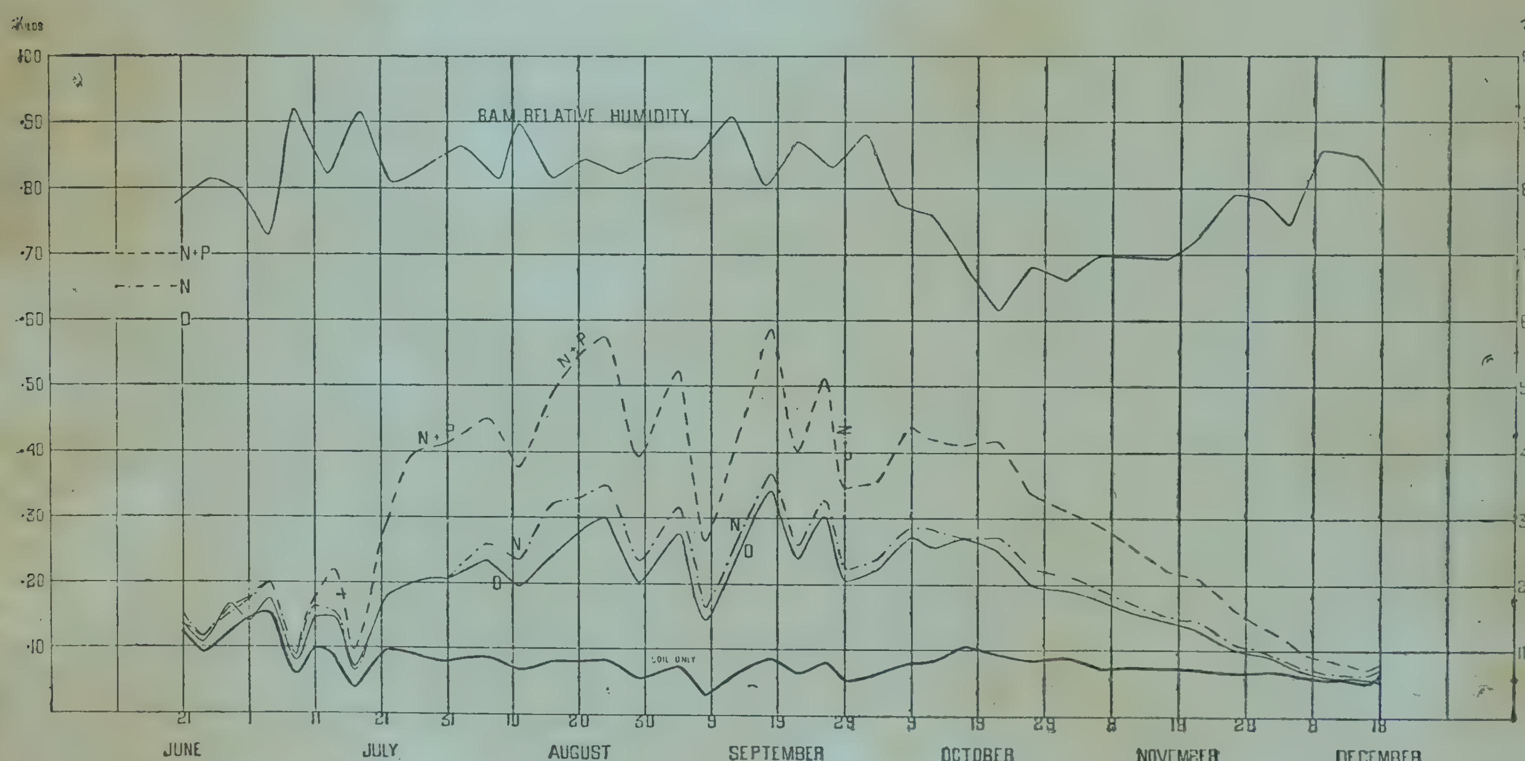
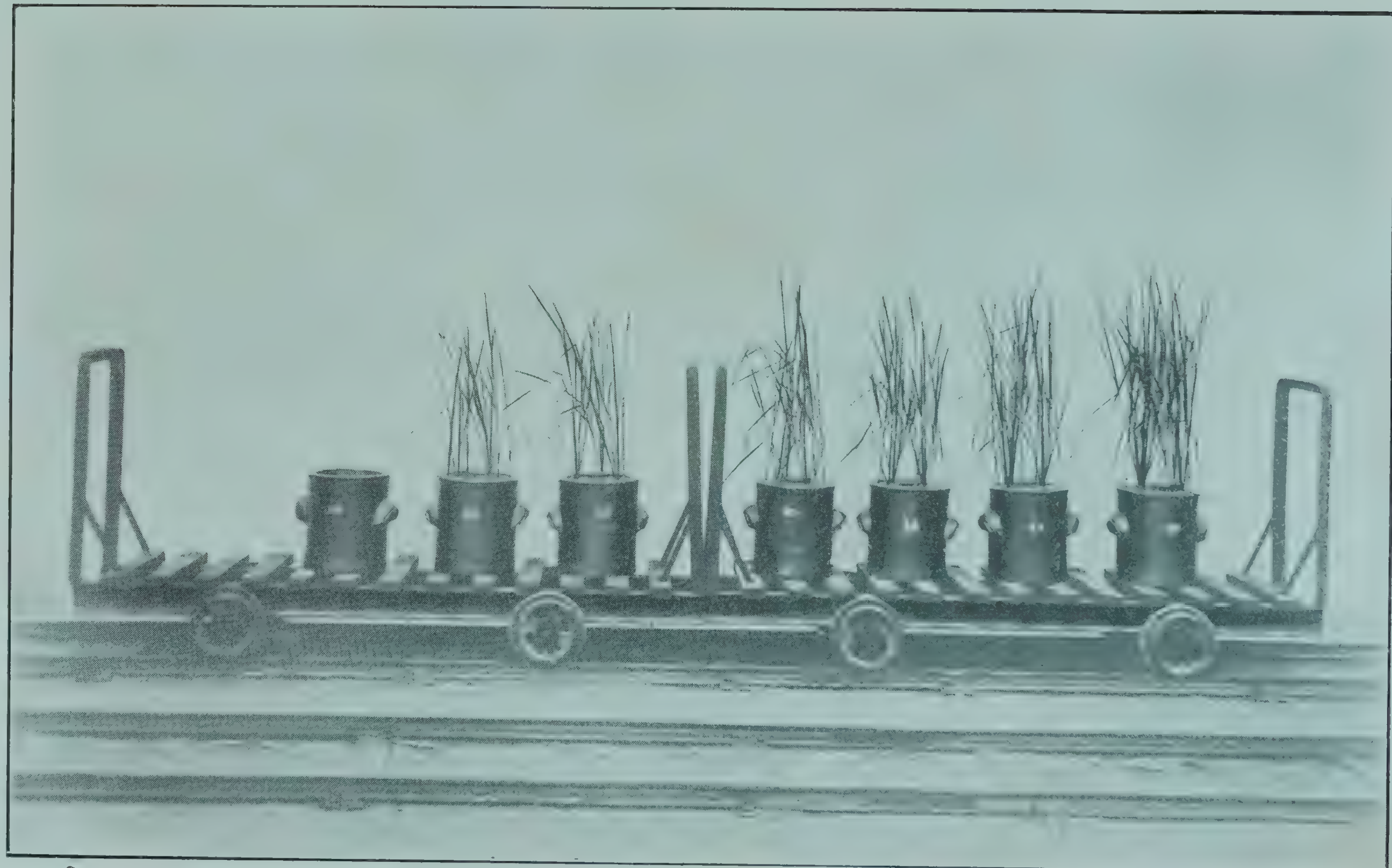


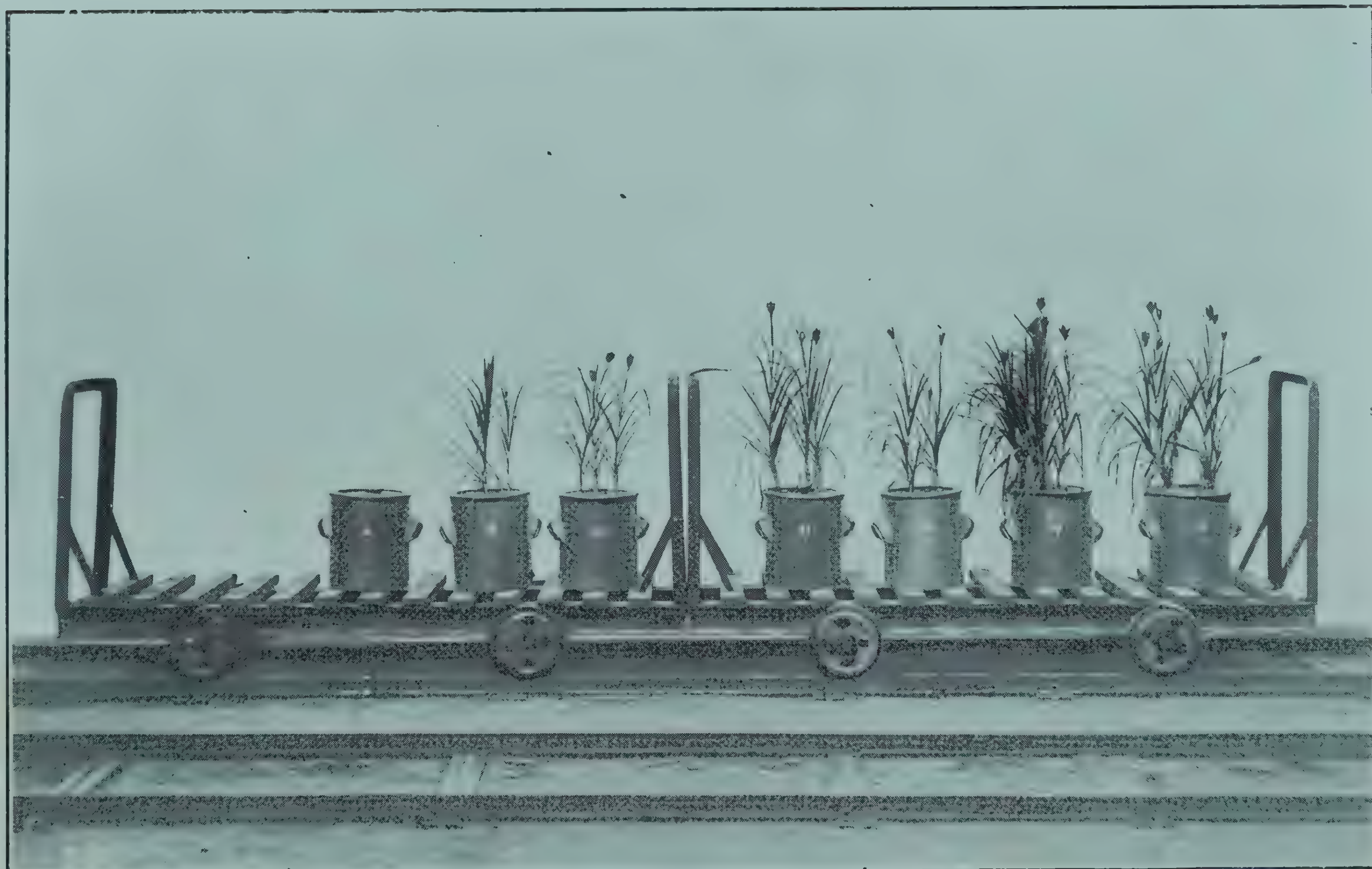
PLATE XV.



RICE, 1908.

23, 24. No manure.
25, 26. Nitrate only.
27, 28. Nitrate and Superphosphate.

PLATE XVI.



MURWA, 1908.

9, 10. No manure.
11, 12. Nitrate only.
13, 14. Nitrate and Superphosphate.

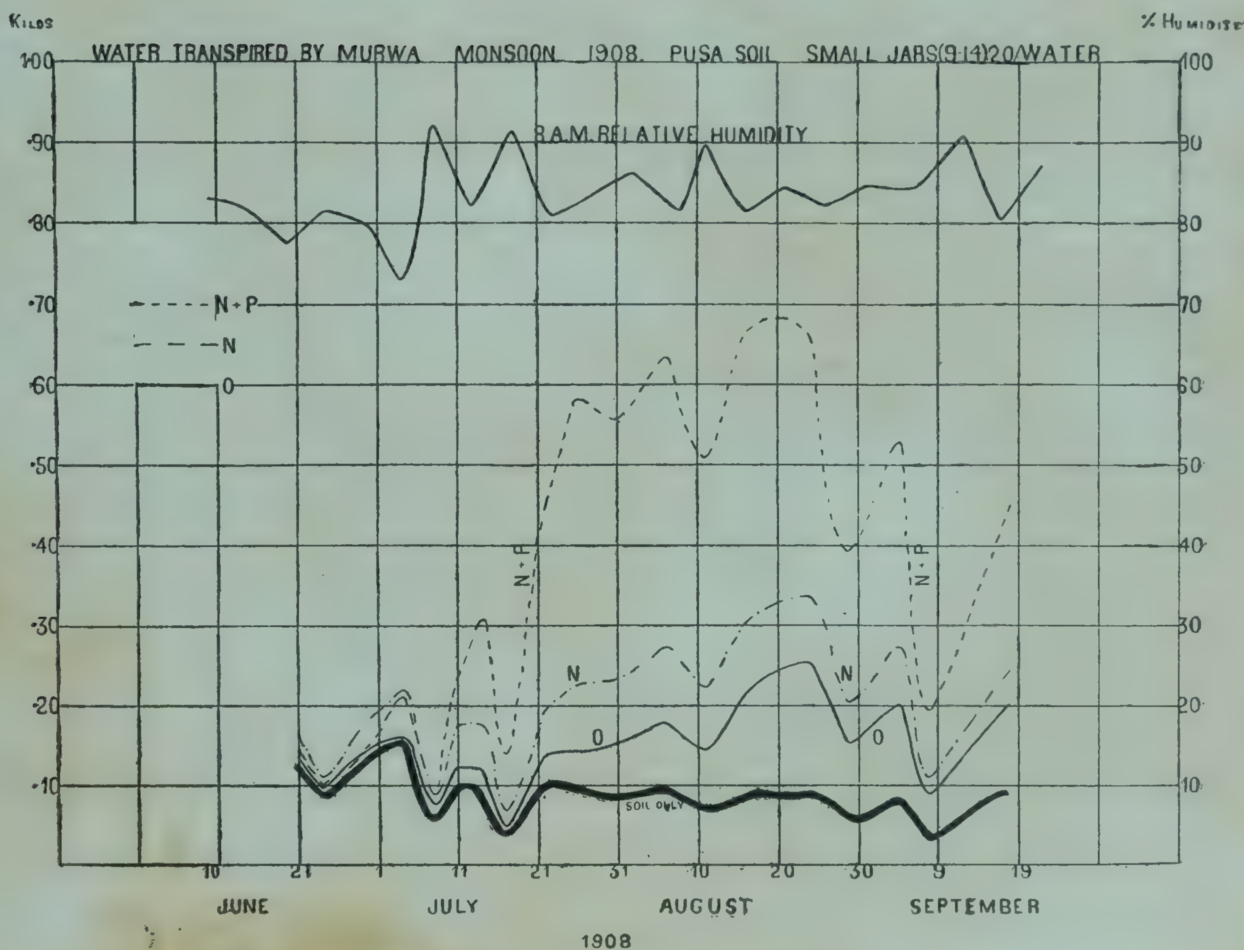
STATEMENT XVI.

ELEUSINE CORACANA (MURWA, RAGI) 1908.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of Sowing.	Date of Harvest.	Dry crop. Seed. Grms.	Dry crop. Total. Grms.	Water transpired. Kilos.	Ratio.
×	A = 9" diam. × 12" deep.	About 14 kilos of Pusa soil.	20	......	Blank jars		...	..	(7·99)	...
9			20	Nil	9-6-(8	19-9-08	4·2	25·0	5·11	204
10			20	Nil	9 6-08	19-9 08	4·2	26·6	8·08	304
11			20	N	9-6-08	19-9-08	7·2	49·4	15·33	310
12			20	N	9-6-08	19-9-98	4 5	33·2	8·50	256
13			20	N + P	9 6 08	19-9-08	22 6	133·3	35·37	265
14			20	N + P	9-6-08	19-9-08	22·1	89·1	23·26	261

N = Ca $(NO_3)_2$ = ·005 grm. N ; P = superphosphate = ·01 grm. soluble P_2O_5 per 100 grms. soil.

CHART XVI.



STATEMENT XVII.

Paspalum scrobiculatum (Kodo) 1908.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of Sowing.	Date of Harvest.	Dry crop. Seed. Grms.	Dry crop. Total. Grms.	Water transpired. Kilos.	Ratio.
... ×	A = 9″ diam. × 12″ deep.	About 14 kilos of Pusa soil.	20	......	Blank jars		...	..	(9·74)	...
16			20	Nil ...	10-6-08	13-10-08	8·9	19·5	6·37	326
17			20		10-6-08	13-10-08	7·9	17·0	8·58	326
18			20	N ..	10-6-08	13-10-08	8·3	22·0	5·71	259
19			20		10-6-08	13-10-08	10·3	23·8	6·50	273
20			20	N+P ...	10-6-08	13-10-08	35·5	74·2	23·47	316
21			20		10-6-08	13-10-08	19·2	43·7	13·44	307

N = Ca. $(NO_3)_2$ = ·005 grm. N ; P = superphosphate = ·01 grm. soluble P_2O_5 per 100 grms. soil.

CHART XVII.

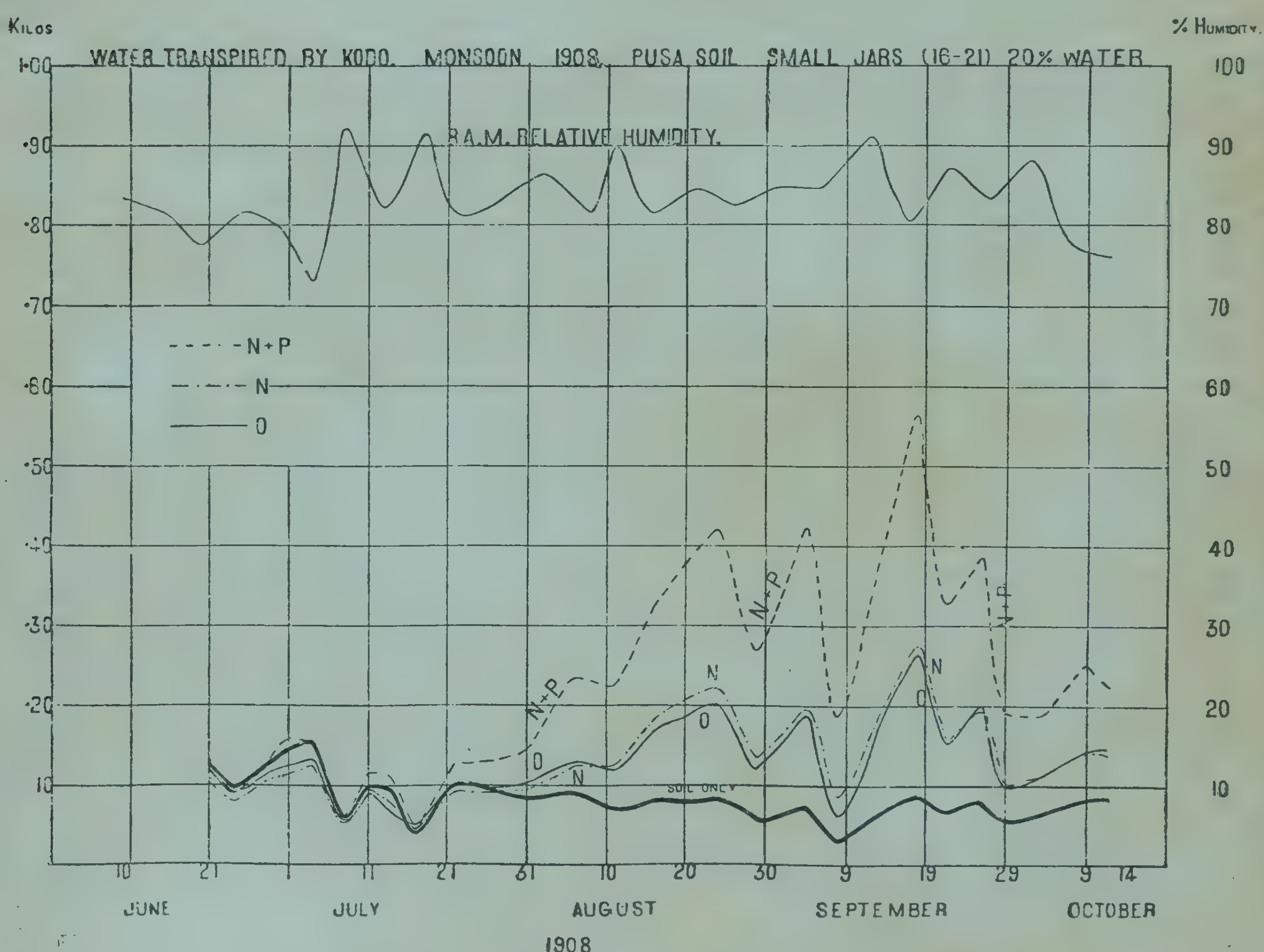


PLATE XVII.

KODO, 1908.

16, 17. No manure.
18, 19. Nitrate only.
20, 21. Nitrate and Superphosphate.

PLATE XVIII.

ARHAR, 1908-9.

29, 30. No manure.
31, 32. Nitrate only.
33, 34. Nitrate and Superphosphate.
35, 36. Nitrate, Phosphate and Potash.

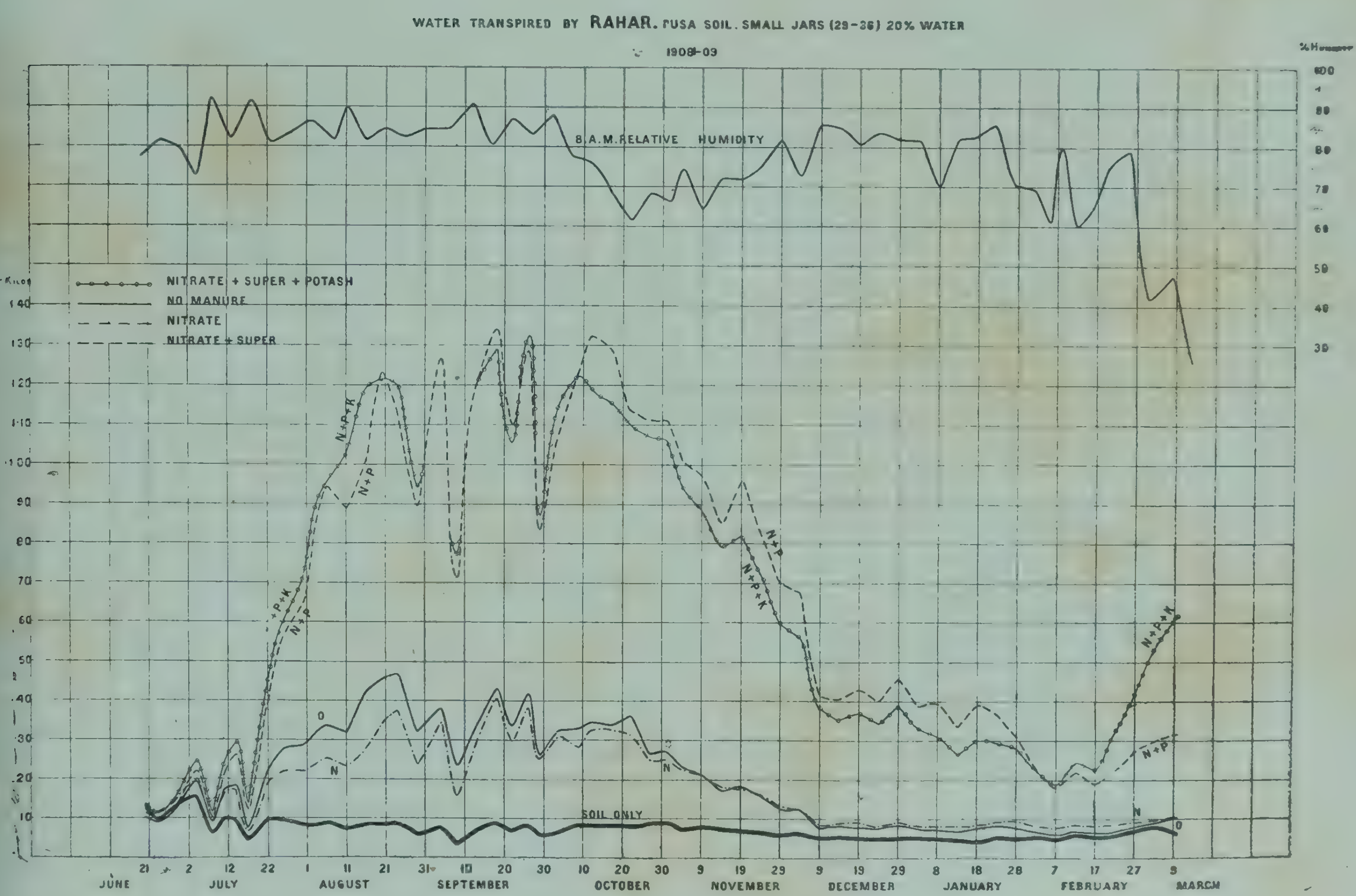
STATEMENT XVIII.

Cajanus Indicus (Rahar) 1908-1909.

Jar No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of Sowing.	Date of Harvest.	Dry crop. Seed. Grms.	Dry crop. Total. Grms.	Water transpired. Kilos.	Ratio.
29	About 14 kilos of Pusa soil.	A″ = 9″ diam. × 12″ deep.	20		Blank jars		...	...	(19·00)	..
30			20	Nil ...	11-6-08	10-3-09	2·4	22·2	26·79	1207
31			20		11-6-08	10-3-09	3·5	40·3	40·74	1011
32			20	N ...	11-6-08	10-3-09	2·4	22·2	24·93	1123
33			20		11-6-08	10-3-09	2·1	24·8	33·90	1367
34			20	N + P ...	11-6-08	10-3-09	33·9	250·4	169·30	676
35			20		11-6-08	10-3-09	35·8	236·2	142·52	603
36			20	N + P + K	11-6-08	10-3-09	28·5	230·2	150·80	655
			20		11-6-08	10-3-09	29·4	265·2	160·47	605

N = Ca $(NO_3)_2$ = ·005 grm. N ; P = superphosphate = ·01 grm. soluble P_2O_5 ; K_2SO_4 = ·005 grm. K_2O per 100 grms. soil.

CHART XVIII.



STATEMENT XIX.

Cyamopsis psoralioides (Guar) 1908.

Jar. No.	Jar size.	Soil per jar.	Water in soil. Per cent.	Manures.	Date of Sowing.	Date of Harvest.	Dry crop. Seed. Grms.	Dry crop. Total. Grms.	Water transpired. Kilos.	Ratio.
×	A = 9″ diam. × 12″ deep.	About 14 kilos of Pusa soil.	20	......	Blank jars		...	...	...	...
37			20	Nil ...	11-6-08	3-12-08	7·3	24·7	27·15	1099
38			20		11-6-08	3-12-08	5·2	16·3	17·35	1064
39			20	N ...	11-6-08	3-12-08	3·7	10·9	9·68	888
40			20		11-6-08	3-12-08	4·5	12·9	15·62	1211
41			20	N + P ...	11-6-08	3-12-08	53·2	153·2	90·48	591
42			20		11-6-08	3 12-08	45·7	121·9	73·59	604

N = Ca $(NO_3)_2$ = ·005 grms. N ; P = superphosphate = ·01 grm. soluble P_2O_5 per 100 grms. soil.

CHART XIX.

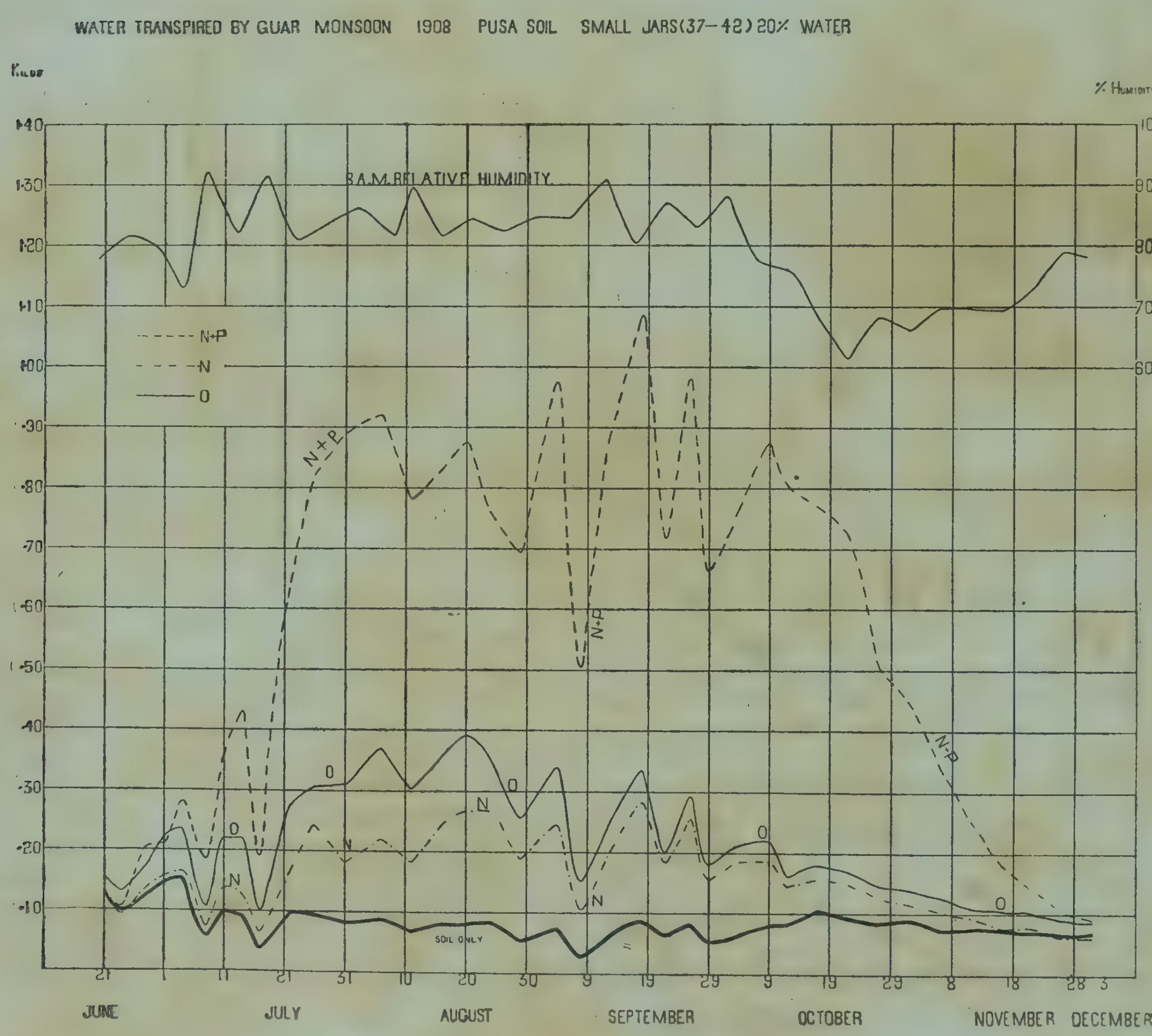
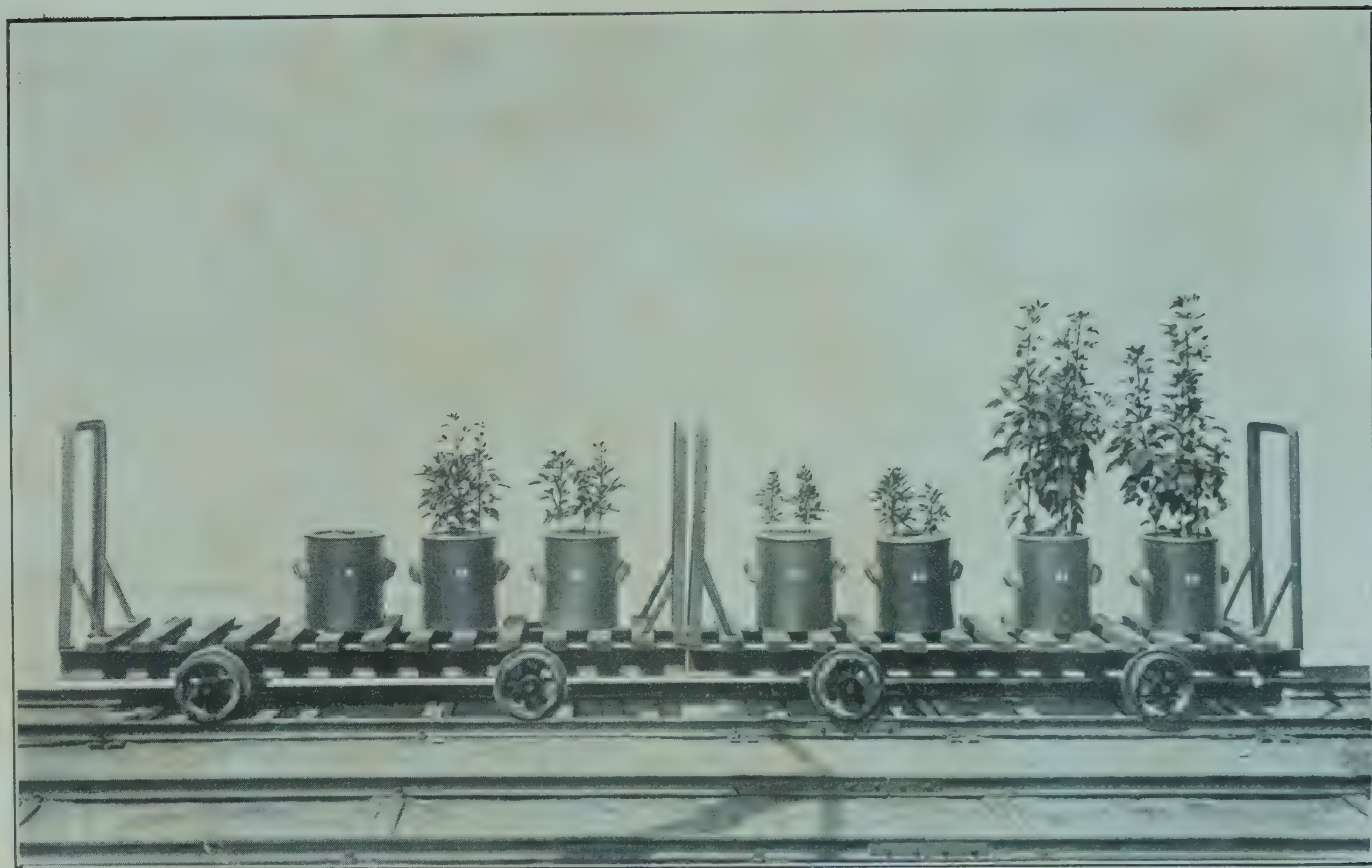


PLATE XIX.



GUAR, 1908.

37, 38. No manure.
39, 40. Nitrate only.
41, 42. Nitrate and Superphosphate.

PART III.

DEDUCTIONS.

The effect of different sized jars.—Cultivation jars of different size have only been used for two of the crops, namely, wheat and maize, but this has been done during several seasons. One may anticipate therefore that any appreciable effect which this factor is liable to exert will be brought out in the series. For a complete comparison reference must be made to the statements, but it will be sufficient if the ratios obtained by the use of large and small jars of soil, unmanured, and manured with nitrate and phosphate or oil-cake and phosphate, and containing a high proportion of water, are here set out.

STATEMENT XX.

Crop.	Soil.	Manured.		Unmanured.	
		Small Jars.	Large Jars.	Small Jars.	Large Jars.
		Ratio.	Ratio.	Ratio.	Ratio.
Wheat ...	Pusa ... 1906-7	574	515	829	955
,, ...	,, 1907-8	725	505	1,133	821
Maize ...	,, 1907	382	295	604	429

This comparison shows that almost uniformly a lower ratio is obtained by the use of large jars, that is, a large mass of earth, and the same has been found quite as uniformly in other experiments. On the whole, the experience gained indicates that the use of large jars containing about 50 kilos of soil offers distinct advantages; some plants such as maize and juar develop much more perfectly in these than in jars holding only about one-fourth the weight of soil. The effect on the ratio may be stated to be quite 10 to 20 per cent.

The effect of the proportion of water in the soil.—The experiments of the two cold weather seasons 1906-07, 1907-08 and the monsoon 1907, included soil containing materially different proportions of water. Attention has already (page 142) been directed to the fact that it is not possible to maintain a *constant*

proportion of water in the soil in pot-cultures and that indeed the amount of water transpired by vigorous plants growing in small jars occasions a very considerable diurnal variation. Among the advantages attending the use of the large jars is the maintenance of a more uniform proportion of water in the soil. We may however compare some of the ratios obtained from plants growing in soil with certain "nominally fixed" proportions of water, for if this factor controls the ratio in an important degree, it should become evident where the differences in the proportion of water are as great as those adopted.

STATEMENT XXI.

Crop.	Soil.	Manure.	Percentage of water in soil.		
			10	15	20
			Ratio.	Ratio.	Ratio.
Wheat	Pusa ...	Nil.	900	653	829
		,,	941	1,060	955
		,,	634	...	1,133
		,,	696	...	821
		Manured.	543	540	574
		,,	593	504	515
		,,	571	...	725
		,,	446	...	505
Maize	,,	No manure.	459	368	604
		Manured.	289	323	382
		Nil.	500	589	381
		Manured.	309	281	295
		Nil.	450	421	429
		Manured.	262	286	295

Of these it cannot be said that the ratio is generally, and still less uniformly, affected by the amount of water in the soil. There is on the whole a larger number of cases in which it is higher with the moister soil than the reverse. On the other hand, the development of "unmanured" plants has been very imperfect in many cases and the ratios consequently somewhat less reliable. On the whole, there is nothing in the evidence to show that the ratio is affected by this factor in so far as these experiments go. At the same time they are distinctly limited; only one soil was employed and the lowest proportion of water employed was 10 per cent. Whether the *ratio* would be affected

by lower proportions of water in this soil, and in how far it would be affected in other soils, one cannot say. As a matter of fact, we are here broaching an entirely different subject, namely, in how far water is "available" to plants in different soils. Hellriegel* made experiments on the subject in 1872 and following years, but it is far from being perfectly understood. Similarly in regard to a high proportion of water we are largely ignorant of what its effect on crops is. Hellriegel's experiments showed that a maximum development was achieved when the soil contained between 30 and 60 per cent. of that amount of water which would "saturate" the soil. Unfortunately the determination of this "saturating" proportion is not simple or accurate, and it becomes correspondingly difficult to decide what either 30 per cent. or 60 per cent. of this is.

So far as India is concerned, our chief object is naturally the determination of the *smallest*, and not the largest, amount of water which should be in a soil, and the upper limit is only of importance in cases of waterlogging.

The effect of manure.—By far the most marked feature of the experiments is the effect of manure on the ratio. Confining attention for the moment to a comparison between the produce of unmanured soil and that manured with nitrate plus phosphate, a glance at the statements shows that the ratio for wheat is only about $\frac{2}{3}$ in the latter case to what it is in the former. The effect on the ratio for maize is often equally great though this is not uniformly the case. The ratios of rahar, guar, barley, oats, gram and peas were all similarly affected ; the ratios for the remaining crops were decreased in the cases of manured soil, although not affected to a like degree.

As to the characteristic in the manure which is the chief agent in reducing the ratio, the majority of the data are apt perhaps to give the impression that the superphosphate has played this part. But experiments in another soil negatived this conclusion. It was a soil selected in part because the amount of

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* For a complete account of Hellriegel's experiments *see* Hellriegel's Beitz. zu d. wiss. Grundlagen d. Ackerbaues, pp. 526—598

phosphate in it, as shown by Dyer's and other tests, was high, and it was anticipated that superphosphate would not increase the outturn ; an expectation which was realised. In it the best crop was obtained by the use of nitrate only, and here also the transpiration ratio was lowest. The effect of manure depends on the soil. If there is a serious deficiency of phosphate, nitrate will not increase the crop or decrease the ratio as would a mixture of nitrate and superphosphate. As regards potash, the use of sulphate of potash in the manures has in no case markedly increased the outturn, and accordingly the data do not show any change in the value of the ratio as due to this fertilizer. Speaking generally, *the effect of a suitable manure in aiding the plant to economise water* is the most important factor which has been noticed in relation to transpiration.

But one may go further than this. A comparison of the ratios obtained from duplicate jars of manured soil reveals the fact that, whenever the plants of one of the pairs of jars developed more perfectly than the other, the better development has been accompanied by a lower ratio. The magnitude of the effect has varied, but the uniformity of the result is such as to leave no doubt of the fact. The conclusion may hence be drawn that *not only manure, but good tillage, a deep soil and indeed any factor which aids in good development of the crop will tend towards an economy of water.* It presumably also explains why the ratios obtained with large jars of soil are usually distinctly smaller than with small jars, the larger quantity of soil causing a better development of plant and a consequently reduced ratio. We may properly bear this fact in mind when considering the quantities of water required by crops. Those set out on page 178 are deduced from the ratios obtained mostly in small jars of soil, and consequently the calculated quantities of water are probably rather high.

The effect of length of period of growth.—At one stage of the experiments it seemed that the length of the period between seed-time and harvest exerted a material influence on the transpiration ratios ; that indeed this increased with the length of the period.

In the following statement are set out the ratios and the length of growing period for all the crops which have been grown without respect of season.

STATEMENT XXII.

	Period. Days.	Transpiration Ratio.	
		No Manure.	Manured.
Maize	90	450	330
Murwa	100	250	250
Kodo	120	300	300
Sarson	120	740	620
Barley	120	680	480
Oats	120	870	550
Peas	120	830	530
Gram	120	1,400	1,000
Linseed	120	1,000	1,000
Wheat	150	850	550
Juar	150	400	400
Guar	170	1.100	600
Rice	180	1,000	800
Rahar	240	1.100	600

A glance over these ratios shows that in a *general* way those crops which mature rapidly have a low ratio, and the longer lived ones a high ratio ; but there are several conspicuous exceptions. Linseed and gram have much higher ratios than oats, barley, peas or sarson, all of which have the same length of growing period at the same time of the year. The linseed ratio may be somewhat high, but the plant developed very well, especially that grown in manured soil, and there seems no reason to doubt that its ratio is actually much higher than the others named. A similar remark applies to the gram. The difference between the ratios for wheat and juar, which require about equal lengths of time for maturity, may reasonably be ascribed to difference of season, because the wheat is grown during the cold weather when, the temperature is comparatively low and the humidity also low, whilst the juar enjoys the monsoon period for the greater part of the time it occupies the land, when both the temperature and humidity are a good deal higher.

The third conspicuous exception is provided by rahar (cajanus Indicus) which enjoys a total growing period very considerably longer than any of the other crops named, and has a ratio, high it is true, but not at all in proportion to its length of growth.

The general conclusion then seems to be that the length of growing period exerts either no influence on the ratio or at least only a modified one.

The nature of the crop.—The question may likewise be asked whether the nature of the crop is a factor of importance. But then what is one to understand by the term " nature of the crop." If it is interpreted as a botanical classification, then one must conclude that there is little or no connection between the natural order and the ratio. At the same time the exceptions which have been dealt with in the last paragraph tend to indicate that for each plant there is a specific ratio, which of course will be modified by the various factors surrounding the plant. In the absence of a better explanation, this seems to be the only legitimate one to offer for the markedly different ratios which have been met with. One would then lay down as a general principle that for each plant there is a specific ratio, the magnitude of which is controlled by various circumstances, and hence that the ratio for a certain crop which has not been tested, can only be prognosticated within certain wide limits.

The effect of temperature and humidity.—Experiments have frequently been made to ascertain the effect of temperature and humidity on transpiration, and the results have shown that the amount of water transpired per unit of time is increased by a rise of temperature and decreased by a rise of humidity in the air. For a more detailed account of such experiments the reader may consult " Hellriegel's Grundlagen des Ackerbaus," pp. 456 to 700, and " Burgerstein's Die Transpiration der Pflanzen," pp. 115-128. The result might indeed be anticipated on both physiological and physical grounds, for with a rise of temperature (within certain limits) the plant's energy is increased, and a rise of temperature would cause from unit surface an increased evaporation ; similarly a decreased relative humidity would aid evaporation. The experiments referred to have been, however, mostly made on plants in this connection for only short periods, whilst for our purposes the effect of the season *as a whole* is required That humidity influences transpiration is readily shown by the daily

records ; on a wet day the quantity of water transpired decreases to say one-quarter or one-fifth of what it is on a fine day. An examination of the charts which have been reproduced in this memoir also shows it very well, for with every serious increase in humidity there is either a check in the direction of the transpiration curve or a dip in it Frequently, more especially during the initial period of growth, the daily increase in the plant's energy is so great that the effect of an increased humidity is insufficient to *decrease* the transpiration and merely checks the daily increase ; but during the later periods the amount of water transpired during wet weather falls to a very small figure. During *continuously* wet weather the protracted suspension of transpiration doubtless accounts for the yellowing of crops.

But although the effect of increased humidity on the daily transpiration is so marked, it remains to be ascertained whether the variation between one season and another is sufficient to cause a measurable difference in the total water transpired, and secondly, whether this will chiefly cause a difference in the weight of crop, or chiefly affect the transpiration ratio ?

Hellriegel sets out (pp. 664—72) a comparative analysis of temperature and humidity during three seasons at Dhame in relation to the mean transpiration ratio for barley obtained from a whole growing period ; this was 366 in a relatively warm and dry year, 1868, whereas it was 263 in a cooler and damper year, 1870. The chief data may be suitably quoted.

STATEMENT XXIII.

Year.	Mean temperature.	Mean humidity.	Ratio.
1868 ...	66	65·7	366
1870 ...	64	71	263

The difference in mean temperature is so slight that to it can hardly be attributed any large part of the difference in the quoted ratios. The chief cause of doubt that may be legitimately entertained of the soundness of his deduction, is that these ratios are in each case the arithmetical mean of a number

of ratios which varied among themselves to as great an extent as the two quoted.

The subject is best considered under two distinct sub-heads. The first relates to the difference of *plant*, the second to the difference of *season*.

As to the *plant*, reasons have already been advanced for assuming that each has probably its particular transpiration ratio. This feature of its development will no doubt be in part if not largely the outcome of its climatic surroundings, not of any one season in particular but of the many during which it has been gradually produced and to which it has become accustomed. Our monsoon crops, for instance, have enjoyed for generations a humid atmosphere, the cold-weather ones a relatively dry one. In this probably lies the explanation why the ratio of the monsoon crops is often so much below those of the cold weather.

In respect of difference of *season* it is difficult, without very considerable experience coupled with a sufficiency of suitable data, to ascertain their effect, and this is well illustrated by the following extracts from our records.

Chart No. XXIV(*a*) shows the 8 A.M. relative humidity in the upper part, and the "mean day temperature" in the lower, for the three cold weather seasons 1906-07, 1907-08, 1908-09. Chart No. XXIV(*b*) gives similar information for the two monsoon periods, 1907, 1908. Regarding the humidity, it must be admitted that the 8 o'clock record is not altogether suitable for our purpose because the relative humidity falls generally so very much as the temperature rises during the day, but an average figure is not available, and the humidity at 8 o'clock is the only record to judge by. The "mean day temperature" is the arithmetical mean between the 8 o'clock and maximum temperature. Since it is known that the greater part of the transpiration occurs during the day time, this mean figure seemed to offer a better basis of comparison than the mean temperature of the 24 hours.

An inspection of chart No. XXIV(*a*) shows that the humidity was generally higher in the season 1906-07 than in

CHART XXIVa.

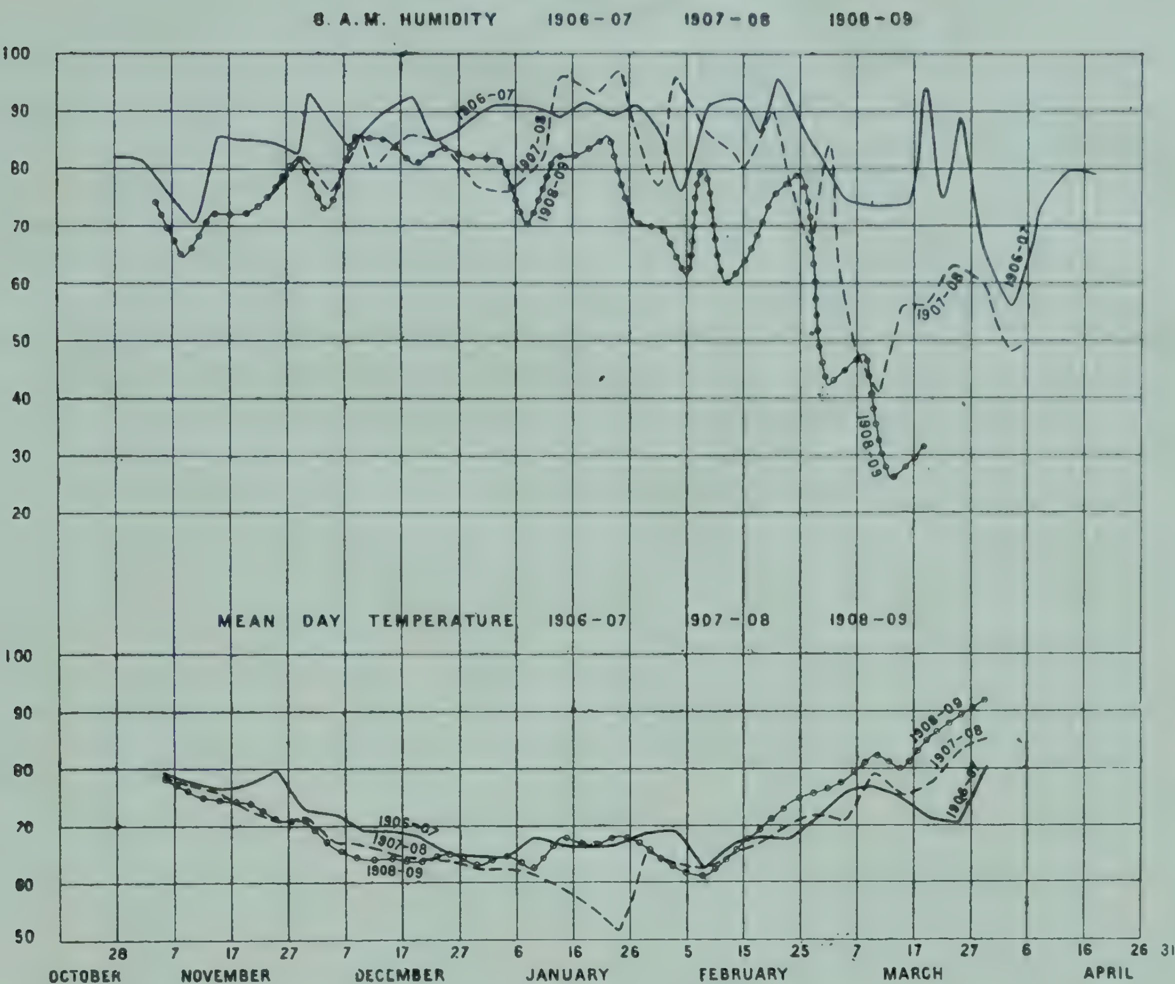
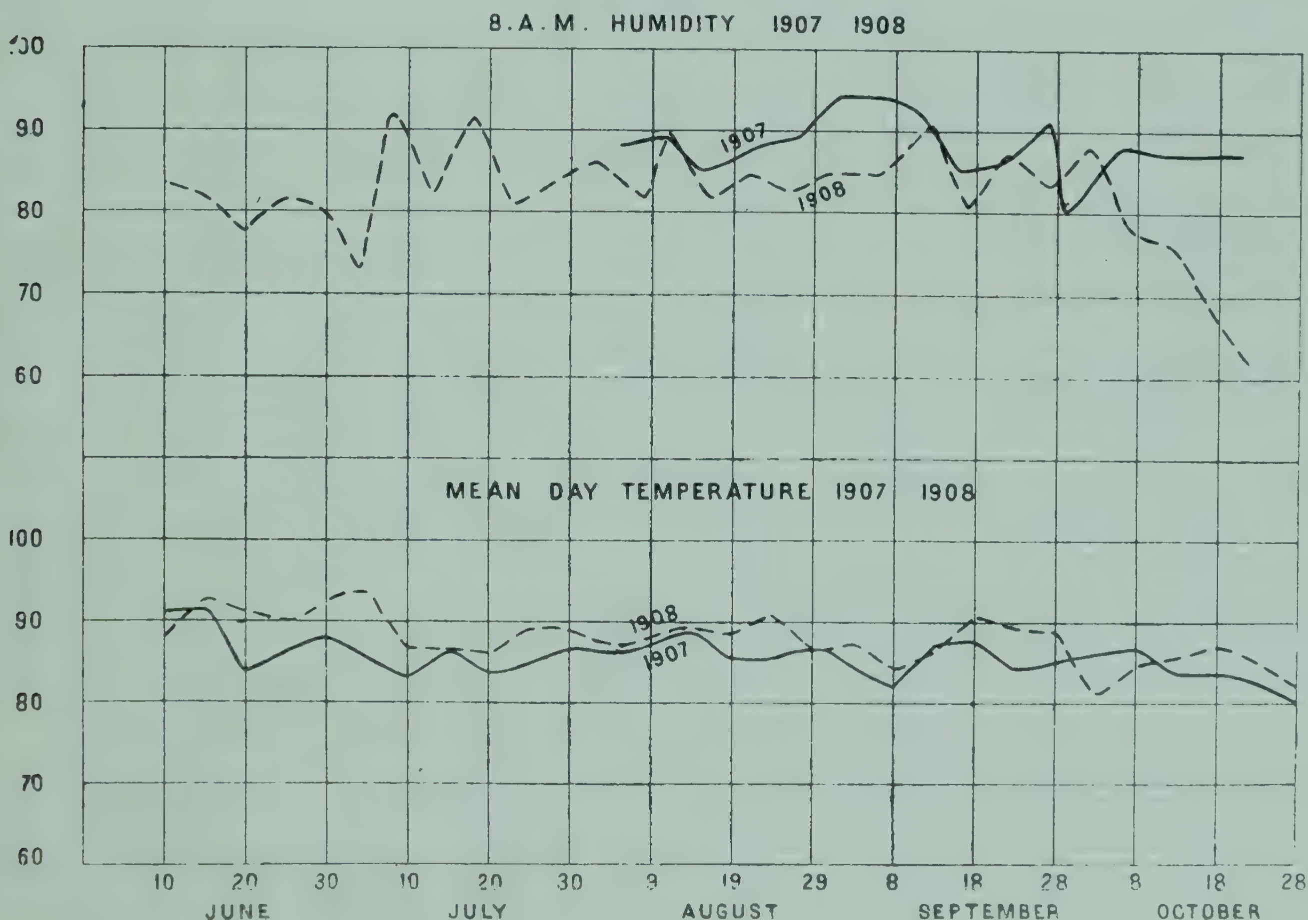


CHART XXIVb.



1907-08 and this again generally higher than in 1908-09; the temperatures of the three seasons were practically alike except for the cold period in January 1908 which cannot be considered likely to affect the total transpiration. If such differences in season affect the general transpiration seriously, it should have been lower in 1906-07 than in 1907-08 and highest in 1908-09. A similar examination of chart No. XXIV(*b*) shows that the monsoon of 1907 was cooler and damper than that of 1908 and the transpiration should therefore have been higher in the latter. Then will come the question as to whether the effect will be a generally increased growth or a higher transpiration ratio. As to the former there are no data; the experiments were not designed for the purpose, and there are so many factors influencing gross outturn in pot-cultures, that it is doubtful in how far these are in this respect comparable between one season and another. The effect on the *ratio* might, however, be perceptible. The data which are comparable are set out in statement No. XXIV. The ratios quoted in this are, in most cases, the means of those obtained in the experiments when the conditions were alike except for the amount of water present in the soil, which is considered to have no influence on the ratio.

STATEMENT XXIV.

	Year.	Jar size.	Manure.	Ratio.
Wheat	1906-07	A	Nil	794
		B	,,	985
	1907-08	A	,,	883
		C	,,	758
	1908-09	A	,,	865
Wheat	1906-07	A	Complete	547
		B	,,	558
	1907-08	A	,,	648
		C	,,	476
	1908-09	A	,,	507
Maize	1907	A	Nil	477
		B	,,	490
		C	,,	433
	1908	A	,,	421
Maize	1907	A	Complete	332
		B	,,	295
		C	,,	281
	1908	A	,,	433

An inspection of these data shows that the ratio for wheat was certainly not perceptibly influenced by the season, and the same remark applies to the maize grown in unmanured soil; the ratio for maize grown in manured soil was certainly lower in the cooler and damper season 1907 than in 1908. The divergence is marked, even if those for the same size of jar only are compared. Even if there had been no other evidence, too much weight would not be applicable to the ratio 433 for 1908; it is the mean of two closely coinciding ratios, but on the other hand the maize did not grow well in these small jars. There were, however, data obtained in 1908 from other experiments, to be quoted on a subsequent occasion, and if these were brought into the comparison, a somewhat lower ratio would be obtained for the 1908 season. This special reference to maize grown in manured soil is not made with the object of proving that sometimes the season affects the ratio, but rather to show how difficult it is to make a really definite deduction on this subject with the aid of only two or three seasons. Then, again, it is to be recollected that the plant itself possesses organs, such as the stomata, wax deposit, hairy growth, etc., which enable it to control transpiration.

The differences of season during the last three years have been relatively very large; the cold weather of 1906-07 was unusually wet and cool and that of 1908-09 unusually dry; there were nearly as great differences in the two monsoons; and since it has been so difficult to perceive an effect on the transpiration ratio obtained during these periods, it is legitimate to conclude that the effect of variation of season on the transpiration ratio is not large, probably not 10 per cent., but it is equally certain that one cannot make reliable deductions regarding the ratio for other parts of India. Perhaps, it would be reasonable to conclude that the ratios obtained at Pusa will be within 25 per cent. of the truth for any other part of India, in so far as climate is concerned.

The diurnal change in transpiration.—A decreased transpiration during the night period has been noticed by a number of

vegetable physiologists. A couple of extracts from our records are of interest since no others exist for India.

STATEMENT XXV.

Date.	Period.		Temperature.		Humidity.	Water lost—kilograms.				
		Hours.	Max.	Min.	8 a.m.	Maize.	Murwa.	Rahar.	Guar.	Juar.
27th July ...	Day	10	93·5	...	78	·57	·55	·65	·87	·55
28th ,, ...	Night	14	...	80·4	...	·12	·15	·16	·18	·13
28th ,, ...	Day	10	93·3	...	83	·66	·70	·81	·95	·71
29th ,, ...	Night	14	...	78·9	...	·15	·15	·19	·19	·17
						Wheat.	Barley.	Oats.	Peas.	Gram.
29th January ...	Day	10	73·7	...	69	·35	·49	·46	·80	·81
30th ,, ...	Night	14	...	41·8	..	·06	·06	·07	·16	·06
30th ,, ...	Day	10	74·5	...	65	·34	·48	·44	·90	·67
31st ,, ...	Night	14	...	39·7	...	·04	·07	·07	·18	·04
31st ,, ...	Day	10	76·7	...	64	·36	·50	·44	·94	·71
1st February ...	Night	14	..	42·2	...	08	·13	·09	·20	·10

These data illustrate the marked difference between the amounts of water transpired during the day and night respectively and at the same time show how the season also affects the process. In July, the amount transpired during 14 hours of the night is about one-fourth as much as during 10 hours of the day time; in January the relative proportion is about 1 : 8. The temperature change in July was about 15°F., in January about 30°F.

The period of greatest water requirement.—An inspection of the charts shows the period during which the major part of the water is transpired. Since the *measurable* transpiration in these jars only commences when the plant is a few inches high, it is only charted from this period, and consequently the curve does not commence until some days after sowing. It rises rapidly immediately the plant commences to "shoot" and remains high, excepting during wet weather, until very near the time of maturity, when it falls again rapidly. It is of interest to tabulate

from the curves and other data the periods during which water is most required.

STATEMENT XXVI.

Season.	First period sowing to first rapid development.	Days.	Second period during which most water is required.	Days.
	Cold weather.			
Wheat 1907-08	Oct. 30th Nov. 30th ...	30	Nov. 30th March 29th	119
Do. 1908-09	Nov. 5th Dec. 1st ...	25	Dec. 1st March 28th ...	110
Oats	Oct. 21st ,, 4th ...	43	,, 4th March 4th ...	90
Barley	Nov. 2nd ,, 1st ...	28	,, 1st March 4th ...	94
Peas	,, 2nd Nov. 24th ...	20	Nov. 24th Feby. 28th ...	96
Gram	,, 2nd Dec. 9th ...	37	Dec. 9th March 9th ...	90
Linseed	,, 2nd ,, 4th ...	32	,, 4th March 9th ...	95
	Monsoon.			
Sarson	Oct. 20th Nov. 9th ...	19	Nov. 9th Jany. 31st ...	81
Maize 1907	July 23rd Aug. 12th ...	20	Aug. 12th Oct. 18th ...	68
Maize 1908	June 8th June 23rd .	15	June 23rd Aug. 30th ...	86
Maize Akola soil 1908 ..	July 4th July 20th	16	July 20th Sept. 30th	71
Maize Palur soil 1908 ...	June 30th July 18th ...	18	,, 18th Sept. 26th ...	70
Shillong soil 1908 ...	July 9th July 30th ...	21	,, 30th Sept. 27th ...	58
Murwa	June 9th July 9th ...	31	July 9th Sept. 18th ...	71
Kodo	June 10th July 21st ...	11	July 21st Oct. 12th ...	83
Juar	June 15th June 26th ...	11	June 26th Sept. 29th .	95
Rice	June 10th July 11th ...	31	July 11th Dec. 8th ...	150
Guar	June 11th June 26th ...	15	June 26th Nov. 23rd ...	150
Rahar	June 11th	...	......	...

The average ratio.—From the data obtained, the following average ratios have been deduced :—

STATEMENT No. XXVII—AVERAGE RATIOS.

Crop.	Unmanured.	Manured.
Cold weather crops.		
Wheat	850	550
Barley	680	480
Oats	870	550
Linseed	1000	1000
Sarson	740	620
Peas	830	530
Gram	1400	1000
Monsoon crops.		
Maize	450	330
Juar	400	400
Murwa	250	250
Kodo	300	300
Arhar	1,000	600
Guar	1,100	600

From these rice has been excluded ; the plant grew very well, and produced a good weight of seed, but this was in less proportion to the straw than is, I think, common in the field, and the seed was smaller than normal. A more potent reason for its

exclusion lies in the fact that it was grown like "dry-land" rice and not with water on the surface of the soil. As a matter of fact, whatever the ratio for rice may be within reasonable limits, the water which its ratio represents per acre cannot bear any proportion to the total water used for wet-land paddy cultivation, and which amounts to something like 100″ or more. Regarding the other ratios, they are useful for the purpose of an approximate estimate of the amount of water required per acre.

As regards the remainder of the crops which have been brought under experiment, most of them have only been under observation for a single season. This does not in itself deduct much from the value of the ratios obtained, because in those cases where repeated tests have been made, namely, wheat and maize, the first ratios obtained have been very well substantiated by the subsequent tests. The chief element of doubt depends on the fact that they have been obtained by experiment in one soil only, and the effect of this factor remains at present an open question. They may, however, be relied on for all soils of the great alluvium.

Another point of some little importance is that they are all probably somewhat *high*. In a previous paragraph (p. 163) it has been shown that the ratio depends in part on the mass of soil in which the plant is developing, a high ratio being obtained when the quantity of soil is only small. It is probable that the ratio in the field is distinctly smaller than those quoted, but at present it is not possible to accurately estimate the difference.

The amount of water required by a crop.—That the amount of water required to grow a crop depends largely on the weight of the crop is self-evident, so that even with a knowledge of the transpiration ratio, an equally accurate knowledge of this second factor is essential in order to estimate the total requirement. It will be also readily recognised that since the outturn of crops varies within considerable limits, it becomes impossible to say how much water is required for say, "a Wheat crop" or "a Juar crop." The most one can do is to assume the position of the agriculturist who, having a knowledge of the general weight of his crops, can calculate with the aid of the transpiration ratio the

total requirement in any specified case. With this object in view the quantities which are set out in statement No. XXVIII have been calculated. It is, however, to be recollected that they are the *quantities transpired*, and do not show how much irrigation water may be needed. It has been assumed that in round numbers an "unmanured" crop (grain and straw) will weigh 1,000 lbs., that a liberally manured one will weigh 5,000 lbs. per acre. If a crop weighs more than 5,000 lbs., the same ratio may be employed as has been adopted for 5,000 lbs. without serious error. These figures may be called in question to a certain extent, especially the one for "unmanured" land, because 1,000 lbs. is certainly very small. But against this is the fact that the pot-culture grown plants in unmanured soil are much smaller than one commonly gets in the field without the aid of manure. The effect of mass of soil in controlling the ratio has been already discussed, and I am sure from certain data which we have obtained in the field, that it has its effect there just as much as in the pot-culture house. Accordingly we must assume that the ratio for unmanured crops grown in the field is not so high as the one obtained with unmanured soil in the pot-culture house. But so far as this point is concerned it is not of first importance, because clearly what we desire more particularly to know is the amount of water required for *large* crops.

If then we consider the higher ratio obtained for plants grown by pot-cultures as true for a very small field crop, and the lower one, obtained by pot-cultures with manured soil as true for a heavy field crop, and adopt intermediate ratios for crops of intermediate weight, we shall probably be as near to the truth as is at present possible. This has been done for the purpose of the estimates set out in the statement. The quantites of water are stated as tons per acre, and as inches. Rainfall is always measured in the latter manner, and irrigation water can be expressed as readily in this as in any other way. The third line of figures against each crop is the most interesting.

The two pulses Arhar and Guar require more water than the other four monsoon crops, and linseed and gram similarly

STATEMENT XXVIII.

Cold Weather Crops.

		Assumed weight of crop in lbs. per acre.				
		1,000.	2,000.	3,000.	4,000.	5,000.
Wheat	Ratio	850	775	700	625	550
	Tons per acre	378	693	940	1,120	1,220
	Inches	**3·7**	**6·8**	**9·3**	**11·0**	**12·1**
Barley	Ratio	680	630	580	530	480
	Tons per acre	304	564	778	954	1,070
	Inches	**3·0**	**5·6**	**7·7**	**9·4**	**10·5**
Oats	Ratio	870	790	710	630	550
	Tons per acre	387	712	950	1,130	1,230
	Inches	**3·8**	**7·1**	**9·4**	**11·1**	**12·1**
Linseed	Ratio	1,000	1,000	1,000	1,000	1,000
	Tons per acre	448	892	1,340	1,780	2,240
	Inches	**4·4**	**8·8**	**13·2**	**17·6**	**22·1**
Sarson	Ratio	740	710	680	650	620
	Tons per acre	330	635	911	1,160	1,380
	Inches	**3·3**	**6·3**	**9·0**	**11·5**	**13·7**
Peas	Ratio	830	750	680	600	530
	Tons per acre	370	670	913	1,070	1,180
	Inches	**3·7**	**6·6**	**9·0**	**10·6**	**11·7**
Gram	Ratio	1,400	1,300	1,200	1,100	1,000
	Tons per acre	625	1,160	1,600	1,970	2,230
	Inches	**6·2**	**11·4**	**15·8**	**19·4**	**22·0**

Monsoon Crops.

		Assumed weight of crop in lbs. per acre.				
		1,000.	2,000.	3,000.	4,000.	5,000.
Maize	Ratio	450	420	390	360	330
	Tons per acre	200	380	524	645	737
	Inches	**2·0**	**3·7**	**5·2**	**6·3**	**7·2**
Juar	Ratio	400	400	400	400	400
	Tons per acre	178	367	536	715	895
	Inches	**1·8**	**3·5**	**5·3**	**7·0**	**8·8**
Murwa	Ratio	250	250	250	250	250
	Tons per acre	112	224	336	448	560
	Inches	**1·1**	**2·2**	**3·3**	**4·4**	**5·5**
Kodo	Ratio	300	300	300	300	300
	Tons per acre	134	238	402	536	670
	Inches	**1·3**	**2·3**	**4·0**	**5·3**	**6·6**
Arhar	Ratio	1,100	970	850	720	600
	Tons per acre	491	870	1,130	1,290	1,340
	Inches	**4·9**	**8·6**	**11·2**	**12·7**	**13·2**
Juar	Ratio	1,100	970	850	720	600
	Tons per acre	491	870	1,130	1,290	1,340
	Inches	**4·9**	**8·6**	**11·2**	**12·7**	**13·2**

a good deal more than the other cold weather crops. But what is still more striking is the fact that, broadly speaking, the cold weather crops transpire a good deal more water than those of the monsoon season. Since it is generally recognised that more rain is required during the monsoon period than the cold weather, the practical agriculturist may be inclined to doubt the correctness of the estimates, but apart from the fact that there is no legitimate reason for doubting the ratio obtained by pot-cultures to a greater extent than has been already suggested, there are several agricultural features *apart from the crop* which will readily account for the greater water requirement of the monsoon period. In the first place, it must be recollected that, at the end of the hot weather, the upper soil is so desiccated that a very considerable amount of rain is required before any crop can be expected to grow. Then too the amount of water lost by direct evaporation from the land during the monsoon must be for most soils greater than during the dry weather. The reason for this is simply that a larger amount of water is quite near the surface of the soil during wet weather than later on, when the upper foot or two feet are partly dry. A proof of this statement is also provided by the Rothamsted drain-gauge data which show that evaporation is greater in a wet year than in a dry one. Again, when considering the effect of humidity on transpiration, the small ratio of the monsoon crops, Maize, Juar, Ragi, Kodo in comparison with the others has been shown to be probably attributable to the nature of the crop, which has for generations become accustomed to growth in the more humid atmosphere of the monsoon period. Finally, in so far as a necessity for an abundant monsoon rainfall is concerned, it is to be recollected that one of its important functions in Upper India is the provision of a thoroughly damp soil for the succeeding cold weather crops. There are thus several reasons for experiencing no surprise that some at least of the rains crops require comparatively little water for *transpiration* purposes. The cold weather crops, on the other hand, develop in a comparatively dry atmosphere, which would naturally tend to cause a more vigorous transpiration.

In conclusion, reference may be made to the influence which the soil has on this subject. In some places where the soil is only a couple of feet thick, as in parts of the Deccan, quantities of irrigation water which are far in excess of those set out in the statement No. XXVIII are known by practice to be necessary ; in other places, one or two irrigations, say 2″—4″ is sufficient to produce heavy cold weather crops ; again, in Behar much of the soil is capable, provided it has been fallow during the monsoon, of producing, with the aid of manure but without rain or irrigation, very heavy crops. During the past cold weather for instance, such crops were produced, after a weak monsoon, with only ·38″ of rain during the cold weather. I am sure this aspect of the subject will be readily appreciated. It is indeed not only a question of how much water crops transpire, but also to what extent a soil acts as a ready reservoir of water. That soils vary in this respect was shown by Hellriegel, but it is doubtful whether its full significance has been generally appreciated. Whilst large cold weather crops could be grown in the soil at Pusa without any rain, the soil at Cawnpore, also liberally manured, could only produce very moderate ones ; and yet the difference in the initial amount of water in the upper soil in the two places was only nominal. The quantities of water mentioned in the statement as being necessary for the transpiration requirements of cold weather crops probably provide an index of the maximum water which might have to be given either as rain or irrigation water in the great alluvium, but in how far the water which is in the soil at the conclusion of the monsoon assists the plant and so reduces the amount of irrigation water or rain required, must depend on the nature of the soil itself. The root range is naturally of importance and more information regarding it is required, and the capability of a soil to "yield" its water to plant roots is of equal importance.

THE NATURE OF THE COLOUR OF BLACK COTTON SOIL.

BY

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Introduction.

The black cotton soil of India covers an area of at least 200,000 sq. miles and ranks as the second most important of our Indian soils. On it by far the largest proportion of our Indian cotton crop is grown.

The origin of the soil and the cause of its dark colour have long been matters of discussion.

As far back as 1829 this soil was described by Christie.* From that date there has been a succession of papers dealing with it; the principal writers having been Newbold,† Hislop,‡ W. T. Blanford,§ Oldham,¶ and Leather.|| These, however, dealt more with the origin of the soil than with the cause of its colour and most of the writers assumed the colour must be due to organic matter. Other theories have been advanced and will be enumerated further on in this paper.

Some years ago Captain A. Aytoun, R.A., published an interesting pamphlet on the "Origin and distribution of the Black Cotton Soils of the Indian Peninsula." He suggests that the black colour is due to organic matter, and that the black soil is

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* *Edin. Phil. Jour.*, VI, 119 (1829): VII, 50 (1829).

† Proc. Roy. Soc., IV, 54 (1838).

‡ *Jour. Bo. Br. Roy. As. Soc.*, V, 61 (1853).

§ Memoirs, Geol. Survey, VI, 235 (1869): Records, VIII, 50 (1875).

¶ Records, Geol. Survey, IV, 80 (1871).

|| *Agric. Ledger*, 1898, No. 2, Soils.

formed in depressions where marsh-loving plants grow up and die. He thinks that it is probable that the cotton plant has degenerated in India and that this degeneration is due to the gradual exhaustion of the soil.

Dr. Leather took up the question about twelve years ago, and made an investigation into the cause of the colour, though he did not quite settle the question. He was never able to finish his investigations, but he came to the conclusion that the colour of the soil was not due to organic matter but to the presence of some black mineral.

Besides the colour of the soil, another point which seemed to need investigation is the wonderful power the soil has of cracking during dry weather. The rents thus formed are constant sources of danger to the horseman riding through the black soil country. In some of the previous writings on the subject, the idea seemed to prevail that the substance causing the black colour was also the constituent which imparted this cracking power to the soil.

One hears tales of the wonderful fertility of certain tracts of this country, and therefore one would expect to see a fairly thick growth of natural vegetation. But a more disappointing outlook than is to be observed at those times when there are no crops on the ground, it is hard to imagine. Bare flat-topped hills of trap rock are typical of the black soil country and always give the traveller notice that he is approaching this type of soil.

The only tree which seems to grow on the soil is the Babul (*Acacia arabica*). Other trees there are practically none. It has been suggested that the roots of no other tree can endure the cracking which goes on in the soil in the dry weather.

The crops grown on the soil are very varied. The main one is cotton. We also get juar, bajri, sugar-cane, wheat, gram, linseed, tur.

The colour of the soil is in many cases a very deep black, but it varies between this and a slaty grey colour. The depth of colour depends on how the soil has been treated or whether rain

has recently fallen on it or no. Wet land freshly stirred generally appears the blackest of all.

The varieties of black cotton soil are numerous. Typically it is a deep black soil. As we approach the hills, it thins out to a lighter colour, and becomes mixed with fragments of rocks. It is very noticeable that black soils occupy the valleys, and as the hills are approached, the colour changes to red.

At Surat, the soil appears to have been all alluvial in its formation. It contains no pebbles of any kind, even Kankar* is rare, and it does not vary in colour throughout its whole depth. In the south of the Bombay Presidency around Dharwar, Hubli, etc., the soil contains numerous small pieces of Kankar.

The nature of the colour of black cotton soil therefore seemed to call for investigation, and Dr. Leather suggested to me that I should take the matter up since owing to pressure of other matters he was unable to do so himself.

Some of the theories which have been advanced at various times as to the cause of the black colour are rather quaint. It was once suggested to Dr. Leather† that the colour was due to the presence of a plant which exuded a black dye from its roots.

The presence of organic salts of iron is also suggested in a D. O. letter from Mr. Oldham to Dr. Leather.‡

As pointed out by Leather, this view cannot be entertained, owing to the great rate of oxidation in these soils at the high temperature.

Oldham§ and Medlicott‖ and Blanford state that "the essential character of a dark colour appears to be due in all cases to the admixture of organic matter, and perhaps the presence of a small quantity of iron." These statements seem based on analyses by Tween. Leather points out that these analyses

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* Pieces of carbonate of lime.

† *Agricultural Ledger*, 1898, No. 2, Soils.

‡ *Agricultural Ledger*, 1898, No. 2, Soils, by J. W. Leather.

§ Geology of India, 2nd edition, Oldham, p. 14.

‖ Geology of India, Part I, Medlicott & Blanford, pp. 133-4.

must have been carried out by igniting the soil, and hence the organic matter found includes combined water.

Leather came to the conclusion that the colour is *not* due to organic matter, but that it is due to the presence of some black mineral and that this might be graphite fused on to silicates. He also made analyses of large numbers of these soils. The reasons put forward by Leather to shew that the colour is not due to organic matter are the following :—

(1) The proportion of total nitrogen is as low as in most other soils which lose only $\frac{1}{2}$ or $\frac{1}{3}$ as much in weight when heated ; this indicates a low proportion of organic matter.

(2) Although the loss on igniting the soils is almost uniformly high, it is suggested that the greater part of this loss is due to expulsion of combined water, because the manner in which these regur soils contract on drying, indicates a high proportion of hydrated ferric oxide or alumina and either of these compounds would lose the water of hydration on being heated.

(3) After boiling these soils with strong sulphuric acid to destroy all organic matter, the siliceous residue is still black.

Experimental.

Presence of a Black Mineral.—On shaking up a sample of black cotton soil in a basin, I observed an appreciable amount of a black substance at the bottom of the vessel. All my samples of black soil were therefore tested for the presence of this substance. The samples were ground very fine, and then treated with very weak hydrochloric acid until no more effervescence took place. Each sample was then shaken up in a porcelain basin. By a process of "cradling," the muddy liquid was thrown off and more water was added, and the "cradling" process repeated. From each of the black soils a residue was in this way obtained, which was seen to be very rich in these black particles. Specimens of many Indian soils, other than black soils, were treated in the same way, but no such black substance was obtained. The soils so treated were from Shillong, various soils from the Gangetic

alluvium, Bangalore, etc. Black soils from Surat, Broach, Poona and Bhusawal (Bombay Presidency), Nagpur, Akola, Betul (C. P.) and Samalkot (Madras) all gave a fair amount of the black substance.

On examining this black mineral, it was found to be strongly attracted by a magnet, and to be very rich in iron. The soil particles were next tested with a magnet, and the particles of all black cotton soils so far examined have been found to be magnetic. The particles of other soils were tested in a similar way. Such red soils as those of Shillong and Bangalore which contain much ferric oxide were also magnetic to a small extent, but to nothing like the same extent as the black cotton soils.

Hence it appears that these soils contain a black substance which is peculiar to them.

Prof. Hilgard, in a recent letter to Dr. Leather, detailing the results of his examination of two black cotton soils, reports that the "microscopic examination of portions of both soils proves the presence of a certain amount of magnetite, and also of some rather indefinite black particles which I take to be partly decomposed hornblende or augite, probably derived from underlying rock just as is the case in the soils resulting from the decomposition of our basalt soils, but the latter yield rather light soils, poor in humus and of reddish tint and nowhere anything like your Indian regur."

Amount of Black Mineral Present.—The presence of a black mineral having been established, it next remained to determine in what quantity it occurs, and also whether this quantity is sufficient to account for the black colour.

The most obvious method for determining the amount present seemed to be by the use of the magnet. However, although an electro-magnet was fitted up, it was not found possible to separate the black mineral satisfactorily by its means even when the soil was ground up with water and the magnet poles immersed in the liquid. Practically every soil particle is magnetic and is attracted to the magnet with the black substance.

After many attempts the following method was adhered to in order to estimate quantitatively the amount of black susbtance present.

25 grms. of the soil were finely ground in an agate mortar. It was then treated with 3 per cent. hydrochloric acid in a large porcelain dish until all calcium carbonate had been dissolved. The dish was then given a rotary movement in the hand. Thus the soil particles were set in motion and the heavy particles of the black mineral settled to the bottom. The muddy liquid was then decanted into a big beaker. More water was added to the basin, which was again rotated as above. The process was repeated many times and at last the residue in the basin consisted of the practically pure black mineral. This was collected. The soil which had been poured into the beaker was again cradled. This was placed with the first lot obtained. The process was repeated until the soil yielded no more black mineral in this way.

The amount of black mineral obtained in this manner from various soils is here set out :—

	Per cent. of black mineral by weight.
Surat soil (1)	2·5
Ditto (2)	1·8
Ditto (3)	1·5
Ditto (4)	1·6
Ditto (5)	1·8
Chikoli, Berar (1)	1·5
Ditto (2)	3·0
Yeotmal, Berar	1·8
Akola, No. 1	1·3
Samalkot, Madras	0·3

It must be remembered that all the black substances have not been removed from the soil by this method. The particles of soil left behind were still magnetic. Only the black substance which is loose in the soil has been thus separated.

It is next desirable to know how much black substance is necessary in order to give a black appearance to the soil. Various amounts of magnetite were added to equal weights of Pusa soil which is very light coloured. When 10 per cent. of the black substance was present, then the soil was very dark.

5 per cent. was found to darken it considerably and even 2—3 per cent. had a great effect. From my experiments I concluded that with a soil which is already a little dark the addition of 3—4 per cent. of magnetite would cause a very appreciable darkening, but not enough to account for the very deep black colour of some of these soils.

It next seemed desirable to try and devise a chemical method for the estimation of the amount of black substance present. After many attempts, however, it was found impossible to do this.

On boiling the soil with strong sulphuric acid as in the Kjeldahl process, the residue obtained in the case of all black cotton soils is more or less black, whereas the residue from all other soils is either white or white and red. This fact was observed by Leather (*Agricl. Ledger*, No. 2, 1898, p. 20).

This residue was still found to be magnetic on washing and drying. On boiling these black residues with hydrochloric acid for some hours, however, and washing and drying, they were found to be no longer magnetic. On again boiling the residues in sulphuric acid, a pure white residue was now obtained which was non-magnetic.

It occurred to me therefore to estimate the amount of black substance present in a soil by first boiling it with sulphuric acid and then estimating the amount of iron which goes into solution by boiling the residue with hydrochloric acid. However, the results obtained by this method were no better than those obtained by mechanical separation owing to the fact that the pure black substance was found to be soluble to a large but variable extent in sulphuric acid.

A few of the results thus obtained may, however, be here quoted : 20 grams each of Pusa and Surat soils and of two soils from Akola farm (Central Provinces), were boiled with sulphuric acid as in the Kjeldahl process but without addition of potassium sulphate. Also an extra lot of 20 grams of Pusa soil to which 5 per cent. of magnetite had been added was similarly boiled. The boiling was continued until all carbon was destroyed. The residues in each case were then collected and washed free from acid. The

residue from Pusa soil without magnetite appeared white. The residues from the three black soils (Surat and Akola) contained many black particles, but there was *no* red oxide of iron visible. The residue from the Pusa soil to which magnetite had been added was seen to contain a good deal of black substance. The iron was now determined in each residue by boiling it for 8 hours with hydrochloric acid on a sand bath, filtering and estimating the iron in the solution with potassium dichromate.

The following table shews the results :—

Soil.	Iron found calculated as magnetite Fe_3O_4.
	per cent.
Pusa (without magnetite)	·04
„ (with 5% ditto)	2·20
Surat soil	1·00
Akola soil No. 1	2·06
Ditto „ 2	2·25

The solubility of the black substance has been found to be somewhere about 55 per cent. in strong sulphuric acid. About 3/5 of the magnetite added to the Pusa soil has been dissolved, so if all the iron is present as magnetite the Surat soil appears to contain 2—3 per cent. and the Akola soils 4—5 per cent. of magnetite.

These figures are naturally very approximate, but they are given as being perhaps some indication of the amount of black substance present in these soils.

An attempt was made to separate the black substance by the use of Thoulet's* solution. This was obtained of a sp. gr. 3·1, but the results with it were not satisfactory. The figures obtained tallied roughly with those obtained by the method of mechanical separation, as was to be expected.

Analysis of Black Substance.—A qualitative analysis shewed the mineral to be mainly magnetite, containing fair quantities of titanium and small amounts of magnesium.

Purification was carried out by grinding with water in an agate mortar and then extracting with a magnet. The substance

* *Wiley's Agric. Analysis, Soils*, Vol. 1, p. 297 (1906).

extracted was again ground and extracted. This process was repeated until microscopic examination shewed the substance to consist of the pure black mineral.

Quantitative analyses of the black substance from various soils were then carried out and are here quoted :—

	Surat Soil. Sample I.	Surat Soil. Sample II.	Yeotmal, Berar.
Iron as $Fe_3 O_4$	77·40	68·73	70·90
Titanium as $Ti O_2$	19·09	14·67	21·75
Magnesium as $Mg O$	3·51	16·60	7·35
Total ...	100·00	100·00	100·00

The iron, titanium and magnesium were determined, and after satisfying myself that the remainder was earthy matter, I assumed in the calculations that the substance consisted of $Fe_3 O_4$, $Ti O_2$ and $Mg O$. This was done as it was found impossible to get the substance *entirely* free from earthy matter. One analysis, however, may be quoted to shew to what extent of purity I was able to bring the samples.

Surat Soil I.

$Fe_3 O_4$	73·24
$Ti O_2$	18·07
$Mg O$	3·32
	94·63

Method of analysis.—The *iron* was determined in the hydrochloric acid solution with titanous chloride.*

Titanium was estimated in the hydrochloric acid solution after reduction with zinc by titration with methylene blue.† This method, after a little practice, was found to give excellent results. On boiling the black substance with hydrochloric acid an insoluble residue was left which contained much of the titanium. This was fused with caustic potash and then dissolved in hydrochloric acid. The titanium was then estimated in this solution by reduction with zinc and titration with methylene blue as before.

* *Sutton's* volumetric analysis.

† *J. S. C. I.*, Feby. 27th, 1909, Eva Hibbert.

Magnesium was determined as pyrophosphate.

The proportion of ferrous to ferric iron was determined in a sample of the black substance obtained from Surat soil. The result obtained was, total iron found 53·01 per cent.; ferrous iron found 16·74 per cent.; ferrous iron for Fe_3O_4 theory 17·67. Assuming the iron is present as magnetic oxide, this result is quite satisfactory. In any case a lower result than the theory for ferrous iron would be expected since the magnesium present probably has displaced some of the ferrous iron.

The method used for determining the ferrous iron consisted in dissolving the substance in hydrochloric acid in an atmosphere of carbon dioxide and then to titrate with potassium permanganate after adding manganous sulphate.*

Properties of the black substances.—The substance when isolated is in the form of lustrous black crystals.

Its sp. gr. is about 5·7. It is only partially soluble in boiling sulphuric acid. After boiling for three hours about 55 per cent. went into solution. This explains why black residues are obtained on boiling these soils with sulphuric acid. It is no more soluble in nitric acid.

It is readily soluble in boiling hydrochloric acid, though a small residue of titanic oxide is left behind.

It is attracted by a magnet though much less readily than pure magnetite; in fact, some particles of it are only with great difficulty picked up with a magnet.

Occurrence of Black Sands in America.—In certain of the Western States of America black sands occur associated with the soils. These sands chiefly occur in Oregon and California, and O. H. Hershey† makes reference to their occurrence on the Isthmus of Panama.

Many investigations have been made into the composition of these sands. The magnetite occurring in them usually contains from five to ten per cent. of titanium and constitutes a greater

* *Chem. News*, 99, 61, 73.

† A remarkable deposit of black iron sand, Isthmus of Panama. O. H. Hershey, Min. and Sci. Press, Oct. 22, 1898.

supply of useful iron than any other available source known on the Pacific coast.*

Associated with these black sands in America, however, are appreciable quantities of gold and platinum, especially of the former.

So far I have been unable to find gold in the black substance I have isolated from the soils, but I have only been able to obtain small quantities of it at present.

Along the banks of most of the rivers in the Deccan and also of the Tapti at Surat may be seen quantities of a deep black sand washed up by the river. These rivers all flow through trap rock districts and black soil, and thus we have another indication of the presence of appreciable quantities of this black substance in the soils. I collected several samples of this black sand from the Tapti at Surat, from the Tapti at Bhusawal (Bombay Presidency) and several other places. The following is an analysis of a sample collected at Bhusawal.

$Fe = Fe_3O_4$	75·09
$Ti = TiO_2$	14·33
$Mg = MgO$	9·16
$Ca = CaO$	1·42
	100·00

After heavy showers of rain in the black soil country I have often noticed a deposit of black sand in the little gullies scoured out in the roadside by the rain.

Oldham† says "many of the dolorites of the Deccan contain iron in the form of magnetite and large quantities of magnetic iron sand are found in the beds of streams which flow over the trap, whilst bands both of magnetite and hæmatite are locally common in the metamorphic rocks." On p. 380 Oldham goes on to say: "It has been stated that magnetite occurs in many of the Deccan basalts, but until far more analyses have been made, it is impossible to say whether any of the rocks contain as large

* Black Sands of the Pacific Slope in 1905, D. T. Day and R. H. Richards, Dept. of the Interior, U. S. Geol. Survey.

† Geology of India, p. 379.

a proportion of iron as the laterite. It is probable that some may, but 15—20 per cent. in any basalt is exceptional."

Amount of Organic Matter present in the Soil.— As mentioned on a previous page, various writers have considered the black colour to be primarily due to the presence of organic matter. I have also set out the chief reasons put forward by Leather to shew that this explanation of the colour cannot be entertained. In addition to this, black cotton soil has been generally considered of late years by officers of the Agricultural Department to be deficient in organic matter. Thus Clouston in a paper on Manuring of Cotton* in the Central Provinces mentions that it is a well-known fact that black cotton soils are deficient in humus, and also he says the cracks help to aerate the soil and thus humus would have more chance of being oxidised. He advocates the use of organic manure and says that nitrogenous manures are found to have a great effect.

Also at certain hilly districts in Bombay, *e.g.*, at Lonavla, it has been found that cake manures and artificial nitrogenous manures have a wonderful effect on plant growth, indicating the soil to be poor in organic matter.

However, Oldham† notes that Leather did not determine organic carbon in these soils and says this would seem to be an important point.

Hilgard ‡ also says: "Leather attributes the black colour of the regur to some mineral substance rather than to humus, but his arguments are not quite convincing so long as the Grandeau test has not been made."

It therefore seemed advisable to determine both the organic carbon and the soluble humus in these soils.

Owing to the absence of gas, etc., the earlier determinations of organic carbon were done by the wet combustion or chromic acid method.

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* *Agricultural Journal of India*, Vol. II, Part II.

† See letter in *Agricultural Ledger* (Leather), 1898, No. 2, p. 24.

‡ *Soils*, Hilgard, p. 415.

Later, however, since the completion of the Agricultural Research Institute, determinations have been carried out by the dry combustion method with copper oxide in a current of oxygen. The latter method, however, besides involving the determination of the amount of carbonate present in the soil, also involved a determination of the alkali carbonates left behind after the combustion, in the soil residue. Had the amount of these latter not been determined, a considerable error would have resulted.

The figures obtained are expressed as percentage of organic carbon in the soil, it not being considered desirable to express this as organic matter by multiplying by any factor.

In the cases where the carbon was determined in the same soil by both methods, the figures are given for the purpose of putting on record the difference to be expected in the results obtained. The amount of organic carbon found in various other Indian soils is also set out.

	Soil taken.	Per cent. organic carbon. Wet combustion method.	Dry combustion method.
	(1) Akola soil ...	...	·83
	(2) 1st class black cotton soil	·94	1·10
	(3) 2nd ,, ...	...	1·00
	Surat soil	·49	·70
	Samalkot soil (Madras) ...	...	1·16
	Akola survey No. 58 ...	·68	...
Not black cotton soil	6 miles north of Sukhtawa (sandstone)	...	0·82
Not black cotton soil	Pusa	0·46	...
Not black cotton soil	Shillong	...	2·63
Not black cotton soil	Bangalore	...	0·46
	Sandy soil, Woburn, England, barley after wheat ...	...	1·19
	* Pasture (Rothamsted) 0″—9″ ...	...	3·60
	* Broadbalk ,, 0″—9″ ...	...	1·57
	* Geescroft ,, 0″—9″ ...	...	1·13

The chromic acid method therefore gives lower results than those obtained by combustion in Oxygen. This was also found to be the case by Warington and Peake,† and by Cameron

* *J. C. S.*, 1906 (89) 595, Hall, Miller & Marmu.

† Trans. C. S., 1880, 37, 617.

and Brazeale.* Hall, Miller and Marmu† shewed that by the addition of a short tube containing red hot copper oxide to complete the combustion the whole of the carbon in the soil can be obtained as carbon dioxide.

The amount of organic carbon in these typical black cotton soils is therefore not unusually high. So that from these figures one could hardly say that the black colour is due to the presence of organic matter.

Soluble Humus.—This was estimated by the method recommended by the U. S. Department of Agriculture.‡

10 gms. of the soil were washed in a Buchner funnel with 1 per cent. hydrochloric acid till the filtrate was free from lime. The soil was then washed with water until the washings were no longer acid. It was then transferred to a stoppered cylinder together with 500 c.c. of 4 per cent. ammonia and allowed to remain with occasional shaking for 24 hours. After standing a further 12 hours an aliquot portion of the liquid was filtered off through asbestos and evaporated to dryness in a platinum basin. The dried residue was weighed and then ignited. Another weight was then taken. The loss of weight is equal to the soluble humus.

	Soil.	Soluble humus per cent.
	Akola No. 1	1·33
	Yeotmal, Berar	1·86
	Surat	0·91
	Samalkot	1·50
	Akola No. 2	1·25
	Akola (Hilgard)	0·70
	Nagpur (Hilgard)	0·90
Not black cotton soil	Shillong	2·49
Not black cotton soil	Pusa soil (sandy)	0·69
Not black cotton soil	,, (clay)	0·89

From the amounts of soluble humus and organic carbon found we cannot say that black cotton soils are rich in organic matter. If we compare the amount of organic carbon in these

* *Jour. Amer. C. S.*, 1903, 26, 29.

† *J. C. S.*, 1906, 89, p. 595, Hall, Miller and Marmu.

‡ Official and Provisional Methods of Analysis, Association of Official Agricultural Chemists, 1908.

soils, however, with the amount of soluble humus, a very interesting fact is observable. The total organic matter in a soil is often calculated from the amount of organic carbon found by multiplying the amount of this by a factor. Thus Hall * states that the organic matter in the soil is sometimes assumed to contain 55 per cent. of carbon. We can therefore roughly assume the organic matter in the soil to contain about half its weight of carbon.

On looking at the analyses of black soils we find that Samalkot soil contains 1·16 per cent. of organic carbon and therefore should contain about 2 per cent. of total organic matter. The soluble humus in it, however, is 1·50 ; *i.e.*, most of the organic matter is in the form of soluble humus. The same is the case with the other black soils examined. But with other soils, such as Shillong soil, we find the organic matter is well over 5 per cent., though the soluble humus only amounts to 2·49 per cent. The same thing is noticeable with Pusa soil. Thus in black cotton soils the organic matter appears to be largely present as soluble humus.

Although it appears improbable that so small an amount as 1—2 per cent. of humus could have an appreciable effect on the colour of the soil, it was thought desirable to test this point. Accordingly various black soils were treated with hydrochloric acid to decompose the "humates" and then washed free of acid.

Each soil thus treated was now divided into two equal portions, one of which was then shaken with 4 per cent. ammonia solution and allowed to settle. The soluble humus was thus extracted and the colour of the soil remaining was compared with that of the portion of soil which had not been treated with ammonia. In every black soil examined the portion extracted with ammonia was distinctly lighter in colour than the other portion. A light-coloured Pusa soil containing only 0·69 per cent. soluble humus shewed no such difference in colour after ammonia treatment, whereas a Shillong soil containing 2·49 per cent. soluble humus

* *The Soil*, 1908 edition, p. 143.

became much lighter in colour after ammonia extraction. The black soils examined were from Surat, Samalkot, and three from the Central Provinces.

These experiments prove that although the amount of humus is not very high in these soils, yet the dark colour is partly due to its presence.

The Cracking of the Soil.—As mentioned already, this soil is noted for the large cracks which form in it during dry weather. Some observers have supposed this property to depend in some way on the presence of the black substance which causes the colour.

It seemed, however, far more likely that it was due to the presence of a large proportion of clay. Accordingly the amount of clay was determined in a number of soils. The amounts found are set out in the table.

	Without preliminary acid treatment.	With preliminary acid treatment.
Akola 1st class B. C. soil ...	.. ...	59·50
Akola black cotton mixed with red	... .	31·18
Surat	......	42·15
Samalkot, Madras	......	59·09
Akola survey No. 51	16·83	26·04
" 12	26·61	48·25
" 58	19·19	23·30
Amrai Farm field, Berar ...	15·90	35·74
Hagari Farm, Bellary ...	16·39	30·78

The method for the clay determination was the sedimentation method described by Hall.* In the second column the sample of soil was first treated with N/5 hydrochloric acid† to dissolve carbonate. In the first column some figures are given which were obtained after simply boiling the sample for half an hour in water instead of the preliminary acid treatment.

As will be seen, the acid treatment shews a much higher proportion of "clay."‡ It was thought worth while to put both sets of determinations on record here.

* *The Soil*, 1908, p. 51.

† *Schloesing, Compt. rend.*, 1874, 78, p. 1276.

‡ See also *Hall. Jour. Chem. Soc.*, 1904, Vol. 85, p. 960

The separated "clay" apparently consisted of much finer particles than usually occurs in soils.

It is therefore quite obvious that the high proportion of clay would in itself account for the "cracking" in these soils.

A practical point here however arises. These soils, though mostly heavy clay soils, behave rather differently from heavy clays such as are known in England. These latter require very careful treatment after rain, and if ploughed when too wet turn up into large unbreakable clods which are only with great difficulty broken down when they dry. On the other hand, black soil can be kneaded up with water to form a very plastic mass, but when this dries, it can readily be broken to a powder. Wet clods of the earth in the field can readily be broken to a powder by gentle pressure. It occurred to me that the explanation of this might be found in the presence of the black mineral. Laboratory experiments on this point, however, did not lead to any very definite conclusion.

Chemical Composition of the Soil.—The composition of the soil does not vary within wide limits. The analyses given are typical ones.

	Nagpur Farm.	Akola.	Average of 18 soils.
Insoluble silicates and sand	68·71	56·11	68·41
Peroxide of iron ($Fe_2 O_3$)	11·25	9·83	7·13
Alumina ($Al_2 O_3$)	9·39	10·68	10·14
Manganese oxide ($Mn O$)	·26	......	·17
Lime ($Ca O$)	1·82	6·59	2·90
Magnesia ($Mg O$)	1·79	2·51	2·27
Potash ($K_2 O$)	·45	0·37	·41
Soda ($Na_2 O$)		0·23	
Phosphoric acid ($P_2 O_5$)	·06	0·08	·06
Sulphuric acid (SO_3)	nil	——	——
Carbonic acid (CO_2)	·44	4·18	1·62
Organic matter and combined water	5·83	9·42	6·58
Total Nitrogen	·05	·03	·03

All the above analyses except that of Akola soil were published by Leather,* though the average of 18 soils was actually

* *Agricultural Ledger*, No. 2, 1898.

taken from Hilgard* who averaged Leather's figures in his own book.

In these analyses both the amounts of iron and of alumina are high. The latter indicates a large amount of clay, which has been found.

Numerous iron determinations have been made in these black soils.

The analyses by Leather shewed an iron content varying between 6 and 14 per cent. of Fe_2O_3.

My own analyses have all shewn a similarly high iron content.

		Per cent. Fe_2O_3
Hagari Farm, Bellary, Madras	...	11·08
Yeotmal, Berar	...	11·53
Akola, No. 1	...	14·36
Surat soil	...	11·29
Samalkot	...	11·25

Origin of black soil.—The origin of black soil has long been a matter of discussion, but it seems to be fairly clear now that it is formed from the trap rock. But this is a question I do not propose to enter into here. A point which this paper does throw light on, however, is that the alluvial black soils such as those of Surat are similar to the sedentary black soils of the Deccan. These alluvial black soils are well seen at Surat (Bombay Presidency) and at Samalkot (Madras Presidency). Surat is at the mouth of the river Tapti and Samalkot at the mouth of the Godaveri and both these rivers flow through the trap districts for most of their course.

Reference may here be made, however, to an examination of some decomposing amygdaloid trap rock underlying black soil found at Bhusawal, Bombay Presidency. A sample of this was finely ground in an agate mortar under water. The fine powder was then cradled to separate any black substance as described on p. 188. The amount of black substance separated amounted to just under 5 per cent. of the rock.

* *Soils*, *Hilgard*, p. 412.

An analysis of this black substance gave the following figures :—

Iron	$= Fe_3 O_4$	84·23
Titanium	$= Ti O_2$	12·18

The black soil appeared to have been formed *in situ* from this "murum," and the above figures are interesting as indicating that a similar black substance appears to occur both in the decomposing trap rock and in the soil itself.

Conclusions.—1. The black colour of these soils is mainly due to the presence of several per cent. of titaniferous magnetite and of 1—2 per cent. of soluble humus. The mineral substance alone would not account for the deep black colour. Here it may be noted that the black colour of certain Hawaiian soils is in part attributed to mineral matter, in this case manganese dioxide.*

2. The soils are not rich in organic matter judged from the European standard, and organic nitrogenous manures appear to give good results on them.

3. The amount of clay is exceptionally high and this accounts for the "cracking" which takes place in these soils during the hot dry weather.

* *J. Ind. & Eng. Chem.*, August 1909.

PLATE I.

THE DATE SUGAR INDUSTRY IN BENGAL.

AN INVESTIGATION INTO ITS CHEMISTRY AND AGRICULTURE.

BY

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PART I.

INTRODUCTION.

It has been remarked by a well-known authority[1] that "we shall never obtain a definite knowledge of the Indian sugar question until palm sugar has not only received more careful consideration but has been made the subject of independent investigation."

It may surprise some to learn how large this palm sugar industry is.

The most recent figures relating to it have been put on record by Mr. Noel-Paton,[2] Director-General of Commercial Intelligence. He puts the total annual yield of palm sugar in India at roughly 480,000 tons. Of this amount it is stated that 125,300 tons are annually produced in Bengal, including Eastern Bengal and Assam. It is presumed that these figures relate to raw sugar, *i.e.*, jaggery or gur. The total output of all sugar in India annually, reckoned as gur, may be put at 3,000,000 tons. Thus it would seem

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[1] Watt's Dictionary of Econ. Prodts., Vol. VI, Part II, page 310.

[2] Notes on Sugar in India, 1911.

that roughly 17 per cent. of India's sugar is produced from palms, but the author thinks that 10 per cent. would be a nearer estimate.

The amount of sugar produced annually throughout the world from various sources, is according to August von Wachtel[1]

From cane	9 000,000 tons.
From beet	8,000,000 tons
From sugar palm (P. sylvestris)	150,000 tons.
From maple	500,000 tons.

The author assumes that these figures relate to refined sugar.

A careful enquiry[2] by the Government of India in 1889 shewed that 168,262 acres were under palms connected with sugar supply. If we take two and a third tons of gur, a safe figure, as the yield of sugar per acre we should get a total yield approaching that of Mr. Noel-Paton's estimate.

Palm-gur and its products are largely consumed in the districts in which they are produced and it is very difficult to get an idea of the amount of gur exported to other districts or of the amount which is refined to high grade sugars.

According to Aubert[3] the palm-sugar producing districts of Upper Burma export annually about 36,500 tons of sugar, presumably as gur.

The Indian Agriculturist[4] in 1900 stated that the annual value of palm jaggery bought by a single Madras firm for refining was more than 15 lakhs. At Rs. 4 per maund this would be roughly 16,000 tons.

In the Imperial Gazetteer[5] we find it stated that in Jessore district alone there were in 1900-1 117 native sugar refineries with an outturn of 235,000 maunds valued at 15·15 lakhs. This is 6,500 tons and would require 16,250 tons of gur for its production. Most of this sugar refined in Jessore goes to Calcutta and is largely used for the preparation of native sweetmeats.

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1 Jour. Ind. & Eng. Chemistry, May 1911, Development of the Sugar Industry.

2 Resolution, dated 20th March 1889.

3 Agric. Jour. of India, Octr., 1911, page 375.

4 Vol. XXV, 1900, page 116.

5 Vol. XIV, page 96.

Mr. Noel-Paton in his notes on sugar previously referred to puts the annual output of refined commercial palm-sugar in India at 64,230 tons valued at Rs. 1,31,02,900 or nearly £ 1,000,000 sterling. Similar figures which he gives for cane sugar are 366,600 tons valued at 7,47,94,600 rupees or £ 5,000,000 sterling.

PART II.

Historical and statistics of production.

Having shown how important an industry the production of palm sugar is, it may be of interest to give a short account of the history of its growth in Bengal. In this chapter the writer does not propose to include other palm sugar producing tracts in India because he has no knowledge of them.

Almost all the palm sugar produced in Bengal is made from the wild date (Phœnix sylvestris). In certain parts of the Sunderbunds a small amount is produced from the palmyra palm (Borassus flabelliformis).

In Jessore, the most important of the sugar producing districts, the industry is an old one. The Collector of Jessore in 1788 enumerated as one of the losses caused by the cyclone of 1787 the injury to the date trees and the weakening of the sugar produce.[1] Later on, in 1792, he wrote that "date sugar is largely manufactured and exported," and in a statistical table prepared in 1791 we find it recorded that 20,000 maunds was the annual produce of the sugar cultivation and that about half of this was exported to Calcutta. At that time, however, there was a considerable production of cane sugar as well.

Production[2] of date sugar greatly increased in Bengal from 1830 onwards, though not to the extent that it would doubtless have done, had it not been checked by the violent fluctuation in its value, which will be referred to presently. The following brief sketch of its progress is necessarily imperfect from the great want of reliable statistics on which to frame it. Previous to the first inroads on the

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1 See report on the district of Jessore by Westland, 1874.

2 The date tree, a prize essay on the manufacture of its sugar, S. H. Robinson, 1858.

East India Company's trade monopoly in 1813 it was hardly known as an article of export. It was manufactured only to meet the wants of native consumers in and around the few places of its production, principally in Jessore and Faridpur districts. It was occasionally transported to the principal markets of the adjacent districts, and especially to Murshidabad and Dacca in the days of their prosperity, when, previous to the British rule, they were the centres of the trade and wealth of Lower Bengal.

Imports of East India sugar into Great Britain gradually increased from 6,282 tons in 1816 to 13,453 tons in 1823. Throughout this period onward till 1837 all sugars from India were loaded with an additional duty of 10 shillings per cent. beyond the rate charged on West Indian sugars. The trade fell off and exports from Bengal to Great Britain from 1830-6 averaged below 6,000 tons per annum. There are no data to show what proportion of exports consisted of date sugar, but these figures show that the production of East Indian sugar met with little encouragement.

Date sugar, however, has always been a favourite luxury with the native population. Its production is preferred in its own districts to that of cane sugar, owing to the more expensive and precarious cultivation of the sugar-cane.

In 1833, Robinson[1] estimated the total production of date sugar at 90,000 maunds, and in 1837 at 100,000. These figures relate to refined sugar, and would be equivalent to about 225,000 maunds, or 8,000 tons, and 250,000 maunds, or 9,000 tons of gur respectively. In 1837 the duties on sugar imported from the East and West Indies were equalised. Exports from Calcutta to Great Britain swelled from 13,403 tons in 1836-7 to 63,084 tons in 1840-41. Trade then became steady and onward till 1847-48, the average exports were 60,000 tons. Here again it is difficult to say what was the proportion of date sugar, but in 1848 the total date crop per annum in Bengal was estimated at 15,000 tons of refined sugar

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[1] Prize essay, page 7.

or 38,000 tons of gur. Two-thirds of this was estimated by Robinson to have been exported from Calcutta and the rest consumed locally. Watt[1] also quotes 38,000 tons as the production of date sugar in Bengal for 1847-8. Thus the production had quadrupled in ten years. High prices ruled throughout this decade.

The first European refinery in Bengal was established in 1829 in the Burdwan district, but owing to the differential duties on sugars exported to Great Britain its operations were restricted to very narrow limits until 1837-38. Encouraged by the equalisation of the duties, competitors then appeared, principally in the vicinity of Calcutta. Their proprietors were not slow to discover the good qualities of date sugar as raw material for refining and they drew largely from the Jessore and Faridpur markets. Supported as they were by English capital they contributed in no small degree to stimulate the cultivation.

Under these encouraging circumstances it might have been expected that date sugar production would have increased more than the estimate had made it in 1848. Undoubtedly during the forties many new plantations were set out, but for the first five years no produce is obtained and the tree comes to full bearing only in its eighth year of growth. We next come to the first great check experienced by the cultivators.

The principles of free trade were rapidly gaining ascendancy in Great Britain and in 1846 Parliament enacted[2] in defiance of and in contradiction to all its previous tendencies for half a century, that in the article of sugar only, slave labour and slave trade should be encouraged. Further that by a scale of duties gradually equalised, the sugar produce of all the world by the end of seven years from that time should be admitted to British consumption on equal terms. As a consequence the English markets were inundated with supplies of foreign sugars and towards the end of 1847 they and our sugar colonies suffered a panic. Many a West India proprietor was

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[1] See Dict. of Econ. Prodts., Vol. VI, Part II, page 115.

[2] Robinson Prize Essay, 1858, page 9.

ruined, while in Bengal all sugar fell in value below the cost of production, and large sums of British capital invested in sugar refineries there were annihilated. In 1851 a second glut and panic occurred in the markets of Great Britain and in January and February 1852 sugars in Calcutta were nearly unsaleable. The date crop would have been a large one but for this discouragement and the date cultivators abandoned the trees.

The business of date tree cultivation being with two or three isolated exceptions entirely carried out by the impoverished ryot, during these two periods of depression at least, all planting of young trees was suspended and all care of young plantations neglected, but it is probable the checks were lasting in their effects, and that the planting since 1848 did not continue in the same increasing ratio as before that year. Still productions continued to increase and in 1857-58 the annual production of dry sugar was estimated at 35,000 tons equal to 88,000 tons of gur, of which two-thirds were exported to Calcutta. Had the cultivation not received the checks mentioned, there seems no doubt the produce would have again quadrupled during the eight years 1850-58 as it did from 1838-46.

Summary of Progress of Cultivation.

	Refined sugar.	Gur equivalent.
	Tons.	Tons.
From 1792 to 1813 it averaged	550	1,370
In 1833 it was	3,300	8,200
,, 1837 ,, ...	3,700	9,200
,, 1848 ,, ...	15,000	38,000
From 1854 to 1858 it averaged	35,000	88,000

So great and steady an increase in cultivation, in spite of partial checks, is sufficient evidence of its value as a remunerative branch of industry. The slave emancipation measures gradually decreased the supplies of sugar from the West Indies and this partly accounts for the rapid rise in date sugar production in the middle of the last century.

In 1849, 10,000 tons or 1/5 of the whole annual quantity exported from India to England was date sugar.[1]

Between 1858 and 1876 the only figures relating to the production of date sugar which we have been able to find, refer only to the Jhenidah and Magurah sub-divisions of Jessore. These are quite sufficient to show that during that period the industry was growing with great rapidity. The table[2] shows the number of native refineries at work in these sub-divisions during the years 1861-73 with their outturn in refined sugar in tons.

Number of native refineries at work.	Year.	Outturn of sugar.
		Tons.
——	1861-2	124
16	1862-3	756
15	1863-4	295
19	1864-5	907
24	1865-6	1,111
36	1866-7	1,381
47	1867-8	1,852
55	1868-9	1,581
67	1869-70	1,951
75	1870-1	2,195
85	1871-2	2,506
113	1872-3	3,805

In 1873, the Jhenidah and Magurah sub-divisions of Jessore alone produced 16,000 tons of gur of which 8,000 tons were refined by native methods.[3]

The reports on the internal trade of Bengal, issued in 1876-77 and 1881-82, give figures showing how rapidly the industry was growing at that time. The table shows the exports of sugar from various districts in 1875-76 and 1876-77 in maunds.

	Refined. 1876-7.	Unrefined.	
		1875 6.	1876-7.
Jessore	142,300	775,000	667,800
Nuddea	36,500	200,000	305,400
24-Parganas	150,600	275,000	274,700

[1] Robinson's Prize Essay, page 191.

[2] Report on the Agric. Statistics of Jessore, Jhenidah and Magurah sub-divisions, 1872-73, by Babu Ramshunker Sen, Calcutta, 1873.

[3] Loc. cit.

Assuming that 40 per cent. is the yield of refined sugar from gur, then in 1876-7, 80,000 tons of date sugar reckoned as gur was exported from the above three districts alone.

The corresponding report issued for 1881-2 remarked that—" raw date sugar is one of the most important manufactures of Nuddea district and it is said that there are no less than 60 sugar manufactories in Chooadanga alone. The sugar industry in Jessore is also said to be decidedly on the increase. The total production of raw sugar in Jessore is reported to be 400,000 maunds (equal to 1,000,000 maunds of gur or 37,000 tons) worth Rs. 16,00,000. There is only one establishment in Jessore for the manufacture of sugar after the European method, at Tahirpur, but no statistics of its outturn have been obtained."

In 1888[1] Bengal (presumably including Eastern Bengal) is again said to have produced 743,000 maunds of date gur. This is only about 27,000 tons. The figures seem to show that the sugar traffic had considerably detracted by this time but Watt admits they may have been much underestimated.

Turning to more recent figures, in the following table is set out the approximate amount of gur produced from the juice of the date palm in Bengal, from 1902-3 to 1910-11. For these figures we are indebted to the Director of Agriculture, Bengal. They are based on the estimates of the district officers.

	Year.	Gur produced from date palm.
		Tons.
Before the partition of Bengal	1902–3	143,892
	1903–4	114,616
	1904–5	162,858
	1905–6	77,838
	1906–7	77,984
	1907–8	72,362
	1908–9	66,572
	1909–10	67,518
	1910–11	66,900
	1911–12	66,930

[1] Statistics of sugar plants and sugar in 1888. Department of Agriculture, Bengal.

In Bengal proper about 15 per cent. of the total outturn of gur is said to be date gur.

In general it appears that the industry began to assume important proportions from about the middle of last century. During the last twenty years or so it appears to have been declining. It seems probable that the causes for this decline are the same as those which are causing a similar decline in the production of cane sugar in India.

A warning might here be added against placing too great reliance on the accuracy of the figures showing the amount of gur produced from the date palm annually.

It seems to the author that estimates of production of palm sugar are best based on the number of trees. The Collector of Jessore has very kindly had counted for me the total number of trees in use for sugar production in his district. The counting has been done during the current year (1912) and pains were taken to get as accurate results as possible. The detailed results are here set out as they may be of use for future record.

District.	Sub-division.	Thana.	Number of trees.
Jessore		Kotwali	780,440
		Keshabpur	489,718
		Manirampur	808,058
	Sadar ..	Jhikargacha	370,494
		Bagherpara	325,558
		Chaugachha	208,719
		Nowapara	173,051
		Total ..	3,156,038
		Bongaon	253,896
		Gaighatha	95,501
	Bongaon ..	Moheshpur	468,924
		Sarsa	218,146
		Total ..	1,036,447
	Jhenidah ..	Total ..	1,640,728
		Magurah	108,608
	Magurah ..	Mahamadpur	83,465
		Salikha	127,872
		Sripur	71,115
		Total ..	391,050

District.	Sub-division.	Thana.	Number of tress.
Jessore		Narail	139,107
		Abhayanagore	137,333
	Narail ..	Kalia	152,273
		Lohagorah	100,834
		Alfadanga	30,909
		Total ..	560,456
		Grand Total ..	5,143,991

Thus in Jessore district alone there are over five million date palms yielding sugar. This total includes old and young trees, as well as those in full bearing.

As we shall see later (p. 351) $21\frac{1}{4}$ lbs. of gur may be looked upon as an average annual yield per tree. Hence the total annual production of date palm gur in Jessore district alone must be somewhere about 50,000 tons. This fairly well corresponds to the estimate of 61,500 tons made by N. N. Banerjee.[1]

I have been able to find some old figures[2] shewing the number of date trees used for sugar making, in each of the districts of Bengal in 1848. I am indebted to Mr. S. G. Hart, Director of Agriculture, Eastern Bengal and Assam, for corresponding figures for certain of the same districts in 1911. The figures are given below for comparison.

Districts.	Number of date palms.	
	1848.	1911.
Dacca	5,000	250,000
Mymensingh	....	600
Faridpur[3]	1,501,000	805,014
Bakarganj[3]	50,000	637,550
Chittagong	100,000	74,000
Tipperah	....	88,000
Rangpur	20	·3,722
Bogra	....	200
Pabna	14,000	49,100
Total ..	1,670,020	1,908,186

[1] N. N. Banerjee. The Date Sugar Palm—Quarterly Journal, Bengal Agricultural Department, January 1908, pp. 161-2.

[2] Published by authority of Government. See Bengal Sugar Planter, Robinson, 1849, Appendix A.

[3] Only these were actually enumerated for 1911.

These figures would seem to shew that the industry has not increased very much in the above districts as a whole, since 1848.

History of English Sugar Factories in Jessore.[1]

In the first half of the 19th century, the establishment of European sugar factories gave a considerable impulse to the manufacture. The first English factory in Lower Bengal was at Dhoba in the Burdwan district and was erected by a Mr. Blake in 1829. When his profits began to decline he formed a company which purchased the works from him for $4\frac{1}{2}$ lakhs. The company had factories at Kotechandpur where they set up English machinery and also at Trimohini but failed about 1842. Kotechandpur then passed into the hands of Mr. Newhouse who brought out the first vacuum pan and Trimohini became the property of a Mr. Saintsbury who worked it for three or four years and then closed it. The factory of Chaugachha was established about the same time (1842) by Gladstone, Wyllie & Co. of Calcutta. It was first under the management of a Mr. Smith and afterwards of Mr. Macleod and it had out factories for purchase at Keshabpur, Trimohini, Jhingergachha, Narikelberia and Kotechandpur. It worked at a profit for only a year or two and after that was discontinued. About 1850, Chaugachha and Kotechandpur alone were in working order and they only worked occasionally, while Tahirpur which was built about 1853 by Mr. Newhouse was worked for only two years and was then sold and converted into a rum distillery.

On the whole the history of the English sugar refineries is not a record of success. The truth is that after they had given a stimulus to the cultivation of the date palm, the trade which they had created was appropriated by native merchants. The demand for native refined sugar was greater than that for the first rate sugar, manufactured by European means, and the Europeans consequently lost the trade.

The following few figures may give an idea of the extent of the palm sugar industry in Madras.

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[1] Taken from the Gazetteer of the Jessore District.

In 1848, Madras is said to have produced[1] 40,000 tons of cane jaggery and 25,000 tons of palm jaggery, but Watt says the palm sugar figures must have been underestimated.[2]

Year.	Tons of palm jaggery.
1883–84	87,200
1884–85	83,700
1885–86	74,000

The accompanying figures shew the total number of palms of all kinds tapped for sugar making for the past five years in the following Madras districts of Godavari, Kistna (5 taluks), South Canara, Malabar and Tinnevelly. The figures were kindly furnished by the Director of Agriculture, Madras.

Year.	No. of palms.
1906–07	2,636,655
1907–08	2,588,410
1908–09	2,133,139
1909–10	1,934,820
1910–11	2,342,446

Messrs. Parry & Co. have kindly sent me the following figures for the last three years shewing the quantity of jaggery bought by themselves or other refiners and distillers in the Madras Presidency. At the same time it must be remembered that a very large quantity passes into direct consumption.

	1908–09. Tons.	1909–10. Tons.	1910–11. Tons.
Palm jaggery	25,400	29,000	26,100
Sugar manufactured	10,800	13,000	13,000

[1] Watt's Dictionary of Economic Products, Vol. VI, Part 2, p. 226.

[2] *Idem.*, p. 227.

PART III.

OTHER SUGAR-PRODUCING PALMS.

Phœnix sylvestris or the wild date is practically the only palm used for sugar production in Bengal. It is also the commonest one used for this purpose in Mysore but it is very little used elsewhere in India. There are various palms whose juice is used in India for the production of sugar.

Borassus flabelliformis.—The fan palm or common toddy palm is the one most used for sugar production in Madras and Burma.[1] It is also used to a small extent for this purpose in the Sunderbans.

Cocos nucifera.—The coconut palm is used to a large extent in Madras for the manufacture of sugar, though it is not so much used there as the fan palm.

Nipa fruticans.—This plant grows in low lying lands by the sea in the Sunderbans, Chittagong, Burma and the Andaman Islands. An alcoholic drink is made from it and I understand a small amount of sugar also. In the Philippine Islands it is used to a considerable extent for sugar making and alcohol[2] production.

Caryota Urens, the sago palm of India, is used to a small extent in Madras. It has been credited with enormous yields at Malabar.

Arenga saccharifera is not used in India for sugar production but is much used for this purpose in the Dutch East Indies.[3] Robinson[4] remarks that these last two palms merit the attention of the Bengal planters.

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[1] Agricultural Journal of India, Vol. VI, Part IV, p. 369.

[2] Philippine Jour. of Sci., April 1911, Vol. VI, No. 2, p. 110.

[3] Jour. Roy. Soc. of. Arts, April 21st, 1911.

[4] Prize Essay, 1858.

PLATE II.

Date Garden.—General View. In background can be seen the shelter for boiling the juice and also the co llecting pots piled for smoking.

PART IV.

THE AGRICULTURE OF THE DATE PALM.

The Date Palm, *Phœnix sylvestris*, grows well over the greater part of India but it is mainly in Bengal and Mysore that it is cultivated for sugar production. Large natural forests occur in Central India and H. D. Chatterjee[1] is experimenting on date sugar production in those tracts.

Area.—In Bengal the total area under its cultivation is put at 150 square miles, 30 square miles of this being in the Jessore district alone.[2]

The industry is chiefly confined to the districts of Jessore, Khulna, Nuddea, Faridpur, Backerganj and 24-Parganas.

Soil.—Kanjilal[3] says that the wild date prefers humid alluvial soils and a moist climate, and further that it is extremely sensitive to shade and avoids clayey soils and water logging.

Cultivation.—The seeds, which are ripe in May, are sown in a nursery in the rains. The young plants are ready for planting out in the following April or May after the first showers of the season have moistened the ground. Kanjilal[4] says they are planted nine feet apart each way: that is 543 trees per acre. Robinson[5] says ten feet apart which is equivalent to 441 trees per acre.

Not much regard however seems to be paid to order or regularity of distance apart of the trees. In the writer's observation trees in plantations are set at any thing from 9 to 17 feet apart and

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1 Is it an experiment or a natural industry. Haridas Chatterjee. Central India Press Mhow, 1901.

2 Hunter's Imperial Gazetteer, Vol. VII, p. 187.

3 Indian Forester, December 1892, p. 451.

4 Loc. cit.

5 Prize Essay 1858.

he would consider 10 feet apart as quite the minimum distance possible. When 4 or 5 years old the green upper leaves are tied up like a bouquet, the lower yellow coloured ones being cut away. At 5 to 6 years old the stem is about $1\frac{1}{2}$ feet high and the tree is ready to be tapped. The spaces between the trees are generally occupied by oil seeds, pulses such as *Phaseolus radiatus* and *Cajanus indicus* or by linseed. Later on even Aus paddy is sometimes grown under the trees. Thus the cost of a native plantation is reduced, whilst the trees benefit by the ploughing, which loosens the earth, and the ground is kept free from weeds.

The quality of the cultivation in date gardens varies greatly. Some of the gardens I have seen have been wonderfully clean, whilst others have been almost choked up with jungle growth.

PLATE III.

Apparatus used in tapping.

PART V.

TAPPING.

The usual articles required for this work consist of (1) a rope (*dara*) 9 ft. long and 1 to $1\frac{1}{2}$ inches thick, which is loosely tied round the operator and the tree, and by means of which a man can climb rapidly and safely ; (2) a plaited palmyra leaf bag (the *thungi*), about 1 foot deep, in which are carried the *daws*, spouts and other articles and to which are attached a wooden hook and two loops of string, the loops going round the waist of the man, and being tied in front and the hook suspending an earthen pot; (3) a piece of canvas or goatskin (the *kolach*), 1 ft. wide, which is tied on the man's back to protect him from the rubbing action of the climbing rope, and (4) three *daws* (bill hooks), one heavy and two lighter ones. All the above are shown in Plate III.

The tapping is a delicate operation commenced in October and done in several stages. With the heavy *daws*, all the old leaves are cut off below the crown, and all the leaves from one side of it leaving only a few at the top, the bases of the petioles and the sheaths being carefully removed (See Plate IV). Then with the lighter *daws* the outer zone of the loose soft tissue is pared off in long slices leaving only a thin covering of it over the sap-supplying inner zone which corresponds to the woody zone in the older wood of all palms. Very great care must be taken not to expose this inner tissue at this stage, otherwise the tree is sure to rot and die, as often happens when the operation is entrusted to inexperienced hands. The experts at this work are called *Siulis* or *Gachis*. After this first operation the trees are given about 8 days rest, by which time the fine covering of soft tissue gets a little hardened and begins to crack. The second operation consists in removing this covering, great care

2

being taken not to cut into the inner zone, which is now for the first time simply exposed. Then comes a rest of 12 to 14 days which brings us to the beginning of November. The *Gachi* as a rule divides his trees into six convenient groups called *palas*, each containing 50 or 60 trees, the number which he can operate on in one day, 300 to 400 being the total number which one man can manage. Next after midday he cuts two eye-shaped notches 3—4 inches long and about $\frac{1}{4}$ inch deep at the base, their lower sides being straight and converging to a point, below which a split bamboo spout is driven into the tree. About 3 or 4 o'clock in the afternoon an earthenware pot is suspended under the spout and the juice which trickles down is collected. The pots are removed early next morning, at 6 or 7 A.M., before the sun gets on them, and the juice boiled into sugar. On the following night juice is again collected generally without renewing the cut though the surface is as a rule cleaned with the hard stem of a palm-leaf. A much smaller quantity is generally obtained than on the first night. On the third evening also more juice is, as a rule, collected, but it is only small in amount and of very poor quality. Each night's juice has a distinctive name given to it. That of the first night is called *Jiran* (rest), of the second night *Dokat* (second cut) and of the third night *Tekat* (third cut). On the fourth and fifth nights no juice is collected. After six days the cut is renewed a little, and for three days juice is again obtained, being given the same names as before. The tapping process goes on in this way throughout the season. The first 2—3 weeks' supply is very valuable, for the gur produced from it, called *Noten-gur*, has a very pleasant smell and is much appreciated by the consumers. It fetches a high price.

Of course it is not to be supposed that in all cases such a regular system of tapping is carried out. Sometimes the trees are cut for 2—3 days in succession, and sometimes they may be cut every fourth day. But such frequent tapping soon destroys the trees.

The *daws* (bill hooks) require much attention. They are daily sharpened on a piece of dry wood sprinkled over with fine sand while

PLATE IV.

THE *gachi* (TAPPER) AT WORK.

the *daws* are new, but with dry potter's clay afterwards. They may even require tempering once or twice in a season. The tip is especially looked to. If too sharp and pointed, it cuts into the trees and injures them, sometimes fatally, and if too blunt, it tears the tissues, whereas a clean cut must be obtained.

The following plan illustrates the daily round of work in the garden:—

ORDER OF TAPPING.

Days.	Divisions of the garden.	Cuts.
1st day	1st portion ..	Jiran or 1st cut.
2nd „	1st „ ..	Dokat.
	2nd „ ..	Jiran.
3rd „	1st „ ..	Tekat.
	2nd „ ..	Dokat.
	3rd „ ..	Jiran.
4th „	1st „ ..	Rest.
	2nd „ ..	Tekat.
	3rd „ ..	Dokat.
	4th „ ..	Jiran.
5th „	1st „ ..	Rest 2nd day.
	2nd „ ..	„ 1st „
	3rd „ ..	Tekat.
	4th „ ..	Dokat.
	5th „ ..	Jiran.
6th	1st „ ..	Rest 3rd „
	2nd „ ..	„ 2nd „
	3rd „ ..	„ 1st „
	4th „ ..	Tekat.
	5th „ ..	Dokat.
	6th „ ..	Jiran.

As a rule there is no dokat or tekat juice in November. In December dokat juice as well as jiran is obtained. In January we have jiran, dokat and tekat juices.

Towards the end of January and thence till the end of the season, the trees are slightly cut for dokat juice as well as for jiran. That is, they are cut on two successive nights (1) for the jiran, (2) for dokat. Dokat juice yielded from a surface cut afresh is called *dokat pocha*. A fair amount of juice drops from the cut

surface during the day. This is collected and is called '*Ola.*' It is very poor in quality and is boiled into molasses which is sold for mixing with tobacco at 12 annas per maund (*katcha*). In normal cases the cut is renewed week after week until about the middle of March, by which time a very deep notch is made into the tree, reaching $\frac{1}{3}$ or at times $\frac{1}{2}$ through it. Each succeeding cut tends to go slightly higher up than the previous one. The next year's cut is made on the opposite side but at a slightly higher level, the tree having grown in height in the meantime. This continued year after year gives the plant its characteristic zig-zag appearance. It is noticeable that trees are almost always tapped only on the East and West side. The first tapping generally takes place on the East side.

The writer has seen trees which have been tapped continuously for almost fifty years. This can be told by the number of notches. The age of a date tree which has been tapped regularly can thus be easily told by adding the number of notches to 6 years, the age at which as a rule, tapping first takes place. The average sap-yielding life of a tree, however, is probably not much more than 25 years. Even then, the old tree is still of some considerable value as fuel.

The yield of sap is greatest in mid winter. The sap collected on calm and cloudless nights gives gur of the best quality. Cloudy and foggy nights affect both the quality and quantity of the juice adversely. It is said that in January when the trees are in full inflorescence, the sap becomes very poor in sugar, though profuse in quantity, and as a rule does not produce good crystals.

Smoking the Pots.—The earthen pots in which the juice is collected are well smoked every morning as soon as they are emptied. It is noticeable, that after smoking the pots are always kept mouth downward on the ground all day, until they are hung up on the trees again in the afternoon. The smoking is done by putting a number of pots mouth downwards over a heap of rubbish such as leaves, date leaves or *bhusa* and then firing the rubbish. The

interior of the pots is thus thoroughly smoked. The treatment is over in a few minutes, and is supposed to help to keep the juice from fermentation. Kanjilal[1] says the smoking gives the pots a glazed surface, and also the alkaline salts of the smoke neutralise acidity, and the heat kills any ferments which may have been produced.

From our own observation we consider the heating effect must be almost negligible as the pots seldom become more than just warm.

A number of measurements were made of the actual temperature to which the insides of the pots attain.

A maximum thermometer was held close to the advancing flame. The highest temperature thus recorded was 53·6° C.

The following are the temperatures reached by a number of pots during the smoking. The temperature was determined by removing the pot immediately the flame had passed it, inserting the thermometer and closing the mouth with a duster.

	Temp. °C.		Temp. °C.
1	26·0	7	33·0
2	34·0	8	33·0
3	27·0	9	29·0
4	26·5	10	29·5
5	28·5	11	51·5
6	28·5	12	51·5

It seems, therefore, uncommon for the temperature to reach much higher than 32° C. Numbers 11 and 12 were exceptionally hot pots and one only occasionally meets with pots which have been so strongly heated.

The following experiments were carried out to find the effect of smoking on preserving the juice.

In the earlier experiments two pots were attached to the cut surface of the tree. One of the pots was smoked and the other

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[1] Indian Forester, Dec. 1892, p. 454.

unsmoked. Two V shaped grooves were cut in the juice yielding surface instead of the usual one and two pegs inserted, one for each of the two pots. The juice from each pot was analysed next morning. Numerous experiments were carried out on these lines but no definite result was obtained. Sometimes the smoked and sometimes the unsmoked gave the best juice. It was decided that tests carried out in this way are useless because—

(1) It is impossible to collect equal amounts of juice in each pot. Indications were obtained that small amounts of juice fermented much more rapidly than large amounts.

(2) It is possible that juice yielded from different parts of the same cut surface is not uniform in composition.

(3) It has been shewn (pp. 327-328) that juice yielded at different periods during the night varies in composition. Therefore unless the rates of flow of juice into the two pots are relatively the same throughout the night, we shall get variations in composition of the juice due to this cause.

It was frequently noticed that the juice in the smoked pots was quite clear, whereas the juice from the unsmoked pots was cloudy.

The effect of smoking was finally decided in the following way:

Four quite new pots were obtained. Two of them were smoked and two left unsmoked. During the evening a large quantity of juice was collected. This was analysed and measured. It was then divided into four equal portions one of which was put into each of the four pots, which were then hung up on trees near the bungalow during the evening. Next morning the juice was analysed from each of the four pots.

The experiment was carried out in an exactly similar way on three successive days. The results obtained are here set out. Jiran juice was used in each case.

Expt.	Date.	Time.	Volume of juice c.c.	Treatment.	Sucrose gms. per 100 c.c.	Reducing sugar gms. per 100 c.c.
1	26-2-11 ..	7-30 P.M.	4,800	Original	15·44	0·57
	27-2-11 ..	8 A.M.	1,200	Unsmoked	14·12	1·94
	,, ..	do.	do.	do.	13·59	2·43
	,, ..	do.	do.	Smoked	14·77	1·47
	,, ..	do.	do.	do.	14·18	1·94
2	27-2-11 ..	9 A.M.	4,800	Original	13·22	0·75
	28-2-11 ..	7-30 A.M.	1,200	Unsmoked	9·95	3·74
	,, ..	do.	do.	do.	8·96	4·86
	,, ..	do.	do.	Smoked	10·72	2·87
	,, ..	do.	do.	do.	10·80	3·24
3	28-2-11 ..	8-30 P.M.	5,200	Original	11·75	0·97
	1-3-11 ..	8 A.M.	1,300	Unsmoked	6·44	4·86
	,, ..	do.	do.	do.	6·33	4·86
	,, ..	do.	do.	Smoked	7·48	4·04
	,, ..	do.	do.	do.	7·02	4·4

A similar experiment was carried out in February 1912. Four new pots were used for collecting juice without previous smoking. The following morning two of these were smoked by the native process. That evening a quantity (900 c.c.) of juice was collected and analysed. 225 c.c. was then put into each of the four pots, and these were hung on trees overnight.

The table shows the result :—

Date.	Time.	Volume of juice c.c.	Treatment.	Sucrose gms. per 100 c.c.	Reducing sugar gms. per 100 c.c.
6-2-12 ..	8 P.M.	900	Original	13·34	0·62
7-2 12 ..	7-30 A.M.	225	Unsmoked	8·39	4·00
,, ..	do.	225	do.	9·48	3·33
,, ..	do.	225	Smoked	11·36	2·50
,, ..	do.	225	do.	Spoilt	3·33

All the juices used in February 1911 for this experiment were faintly acid. The juice used in 1912 was distinctly alkaline.

In every case we see that the juice kept in the smoked pots has not deteriorated so much as that in the unsmoked ones. We must conclude that smoking has a beneficial effect.

It has been suggested that this beneficial effect is due to the alkalinity of the smoke. Accordingly, to test this point, we burnt quantities of the fuel normally used by the native for smoking the pots and aspirated the smoke through measured amounts of standard acid. As a result of several experiments it was found that the smoke contained no measurable amount of alkaline constituents.

It seems possible that the beneficial effects of the smoke may be due to the presence in it of some antiseptic body such as formaldehyde. It is proposed to make an examination of the smoke constituents in order to test this point.

PART VI.

TOURS.

The work is the outcome of two visits to Jessore district. It was first taken up at the end of January 1911 by which time, however, the greater part of the sugar producing season is over. The results obtained on that occasion could hardly be used to judge of the capabilities of the industry, for it is well recognised that towards the end of the season there is a marked falling-off in the quality of the produce.

Accordingly it was decided to spend the greater part of the cold weather 1911-12 in the date sugar districts. By this means only could reliable information be obtained.

In the first place it is of great importance to determine what is the average yield of sugar per tree per season. The estimates of this up to the present have varied within very wide limits.

The losses during manufacture had to be investigated and opinion had to be formed whether or no the industry was possible and worthy of improvement. In this case then data had to be obtained in order to show in what directions the industry could be improved.

The first visit to Jessore district lasted from January 31st to March 6th, 1911. The second and main tour lasted from November 29th to February 14th, 1912. Thus practically the whole of the date sugar producing season was included. About 2,000 individual measurements of yields of juice per tree were made during this time in different parts of the district. The specific gravity of the juice was taken in each case. During the second tour, a garden was selected near Kotechandpur which was kept under careful observation. In this garden 20 trees were taken at random and

the juice carefully measured from them throughout the season, and from four of these trees the juice was regularly analysed in order to see how the amount of sugar in the juice varied throughout the season.

Various other experiments were carried out, such as the loss of sugar during boiling and so on, and these are all described in the subsequent pages.

CHART NO. 1.

TREE NO. 3.

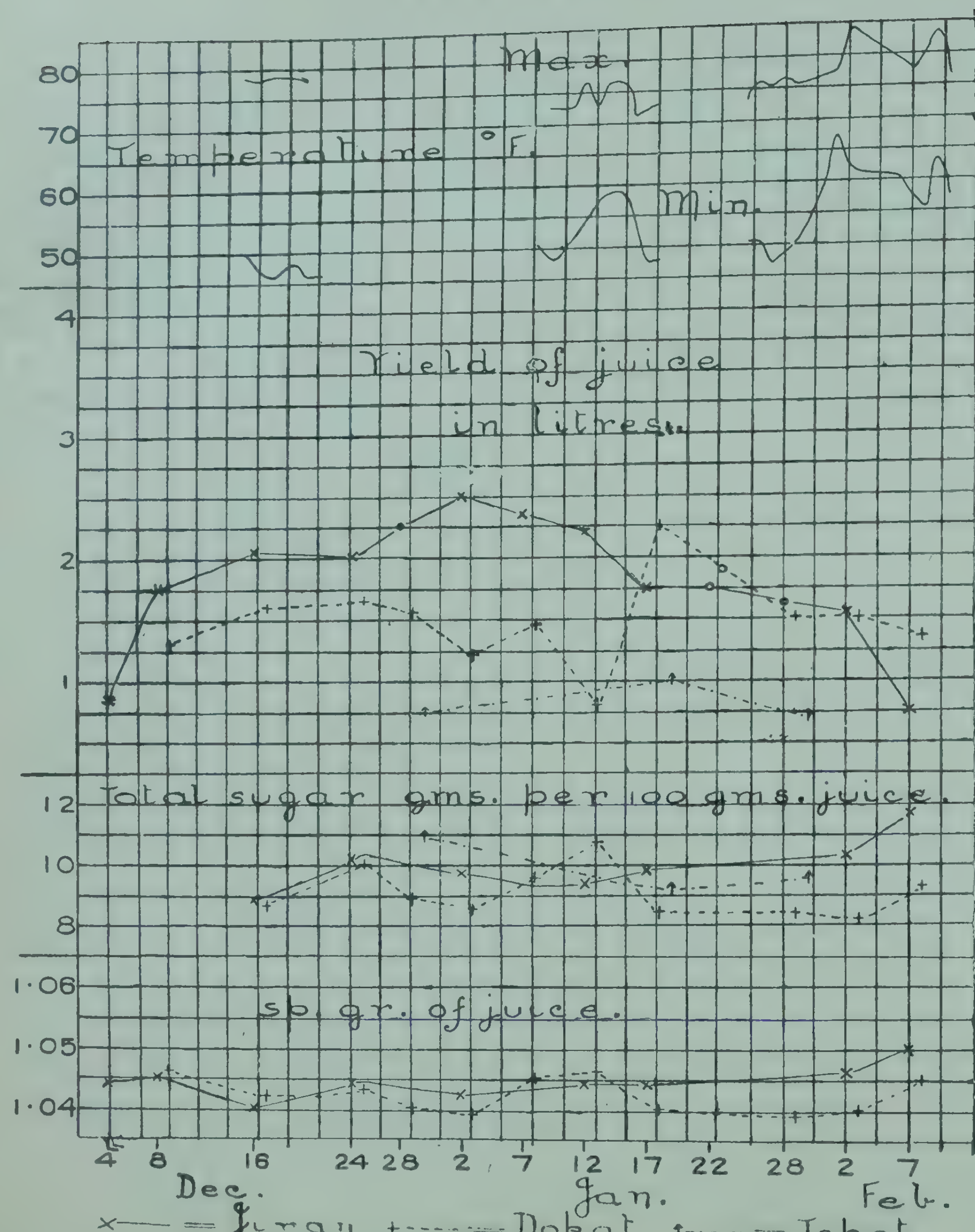


CHART NO. 2.

TREE NO. 11.

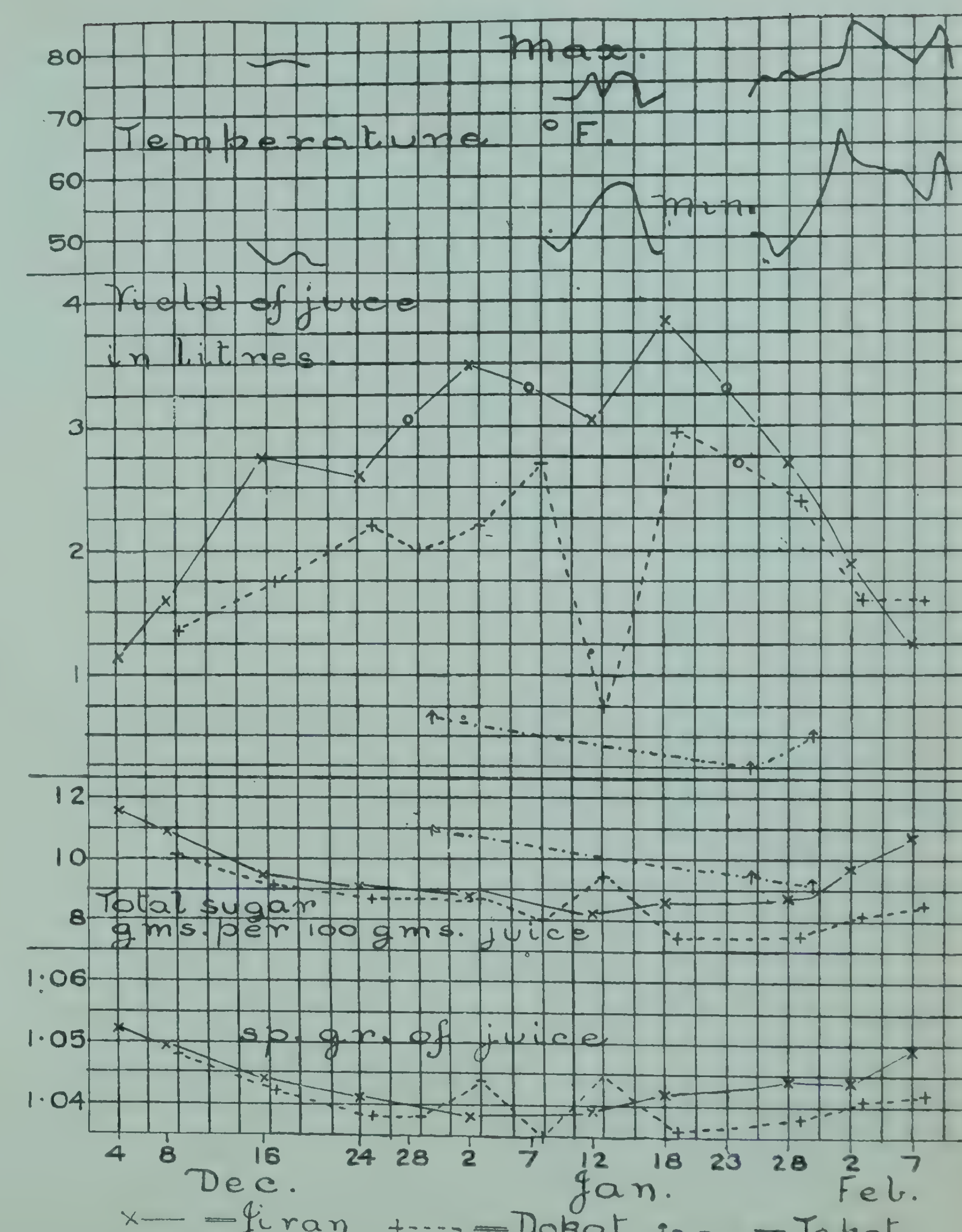


CHART NO. 3.

TREE NO. 16.

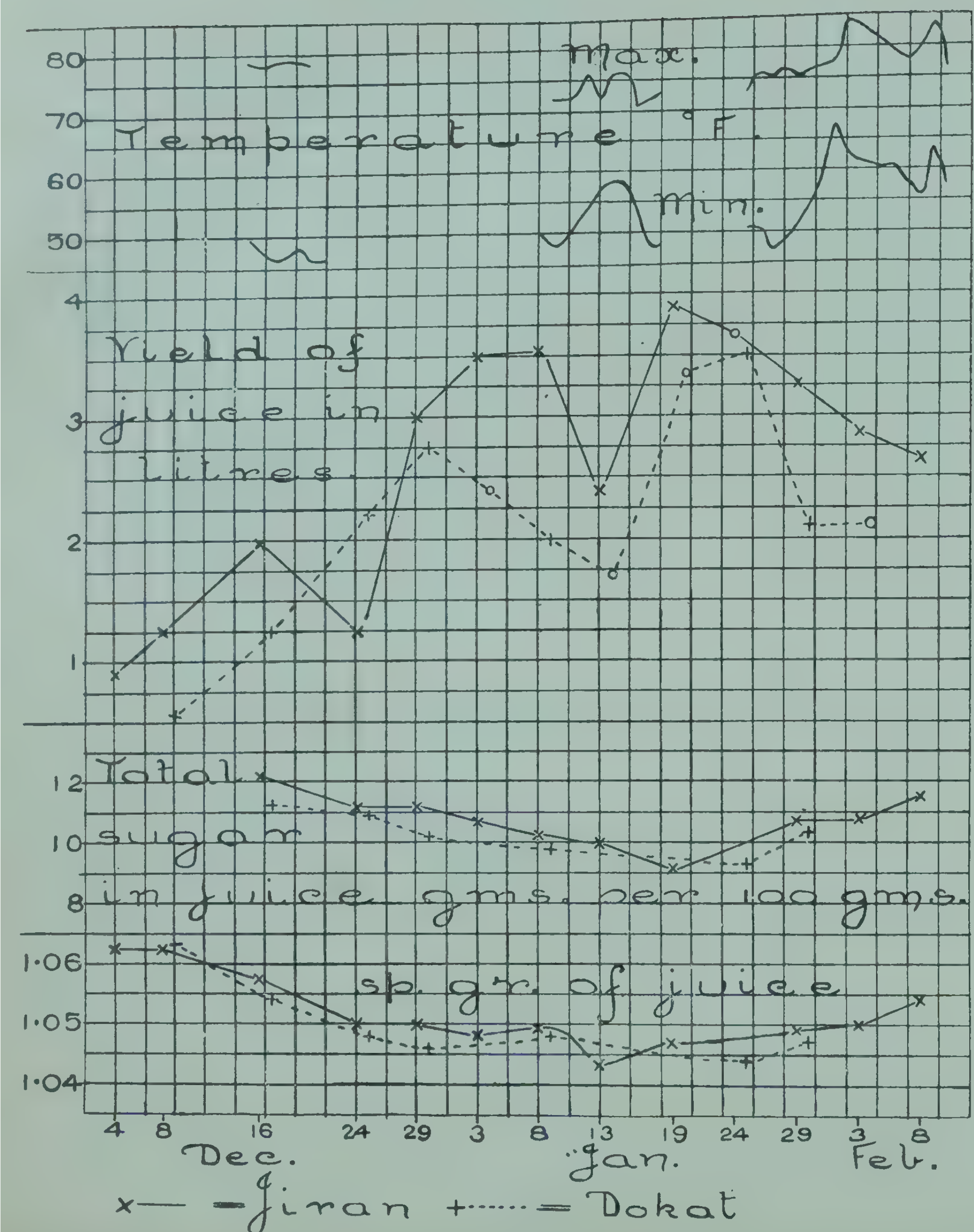
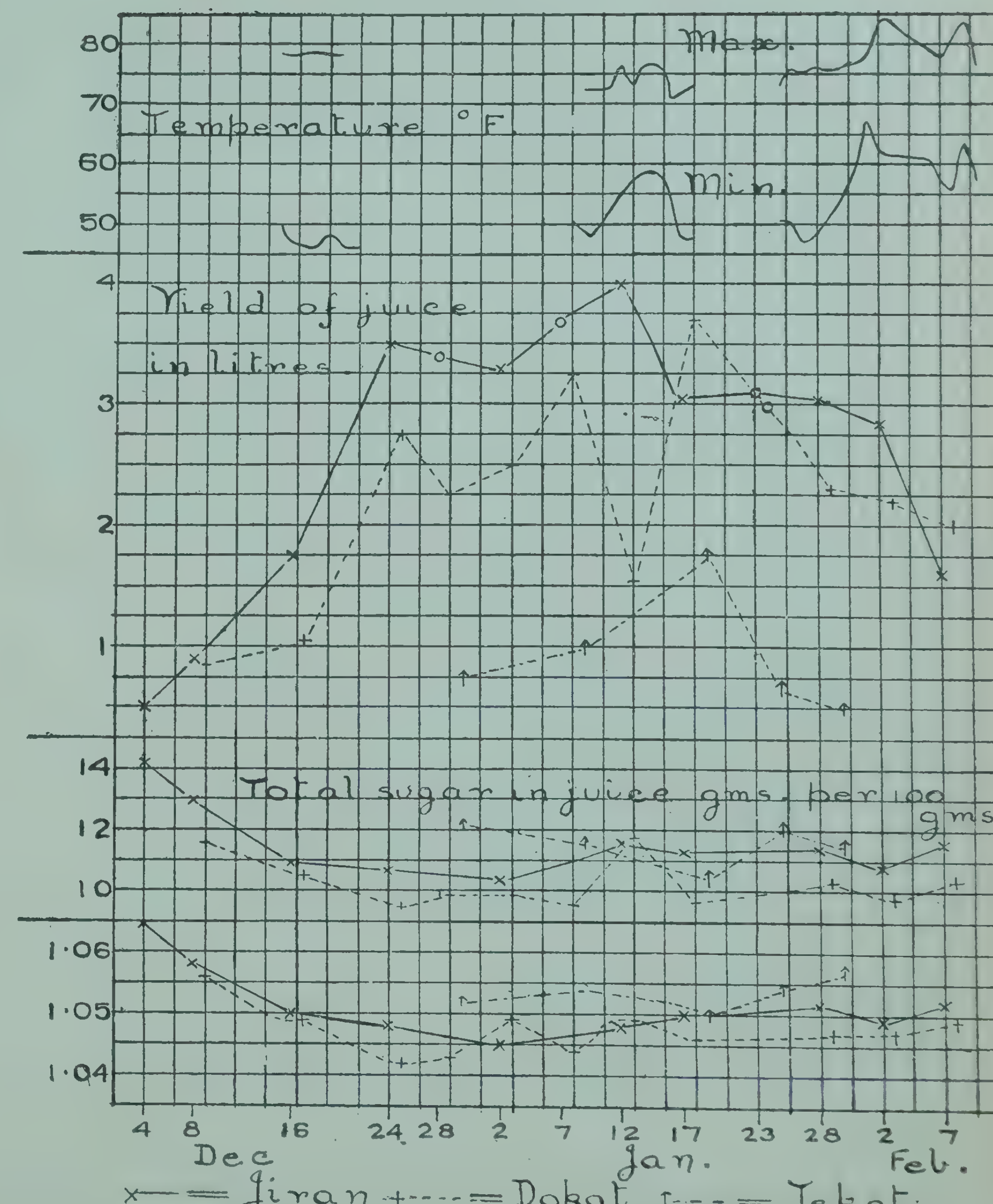


CHART NO. 4.

TREE NO. 20.



PART VII.

JUICE.

YIELD OF JUICE PER TREE.

Our observations show that most of the estimates hitherto made are much too high. Twenty trees of various ages and in various conditions were selected in the same garden and were numbered 1 to 20 and metal labels with the numbers stamped on them were nailed into the trees. Whenever the trees yielded, the juice was, if possible, measured and its specific gravity taken. In the case of trees Nos. 3, 11, 16, 20, the amounts of sucrose and reducing sugar were regularly determined. The data obtained are all entered in the tables. This experiment was carried out in the cold weather 1911-12. Tapping operations commenced very late this season because there was a large area of jute grown in Jessore and the harvesting, retting and marketing of this delayed the date sugar operations beyond the normal. The above trees in consequence did not yield their first juice till December 4th. Moreover it was not possible to always measure the juice. For those days which were missed figures have been inserted in brackets and these have been computed from a consideration of the yields given on the preceding and succeeding occasions. The data for four of the trees have been plotted as curves in Charts Nos. 1—4.

Notes on the tree.	Date.	Jiran, Dokat, or Tekat.	Volume c.c.	Specific gravity.
Tree No. 1	4th Dec. 1911 ..	Jiran ..	600	1·058
8 years tapped.	8th ,, ,, ..	,, ..	1,150	1·056
	9th ,, ,, ..	Dokat ..	1,000	1·058
	16th ,, ,, ..	Jiran ..	1,950	1·052
	17th ,, ,, ..	Dokat ..	1,250	1·050
	24th ,, ,, ..	Jiran ..	2,150	1·050
	25th ,, ,, ..	Dokat ..	(1,650)	....
	28th ,, ,, ..	Jiran ..	(2,250)	....
	29th ,, ,, ..	Dokat ..	(1,650)	....
	2nd Jan. 1912 ..	Jiran ..	(2,250)	....
	3rd ,, ,, ..	Dokat ..	(1,650)	....
	7th ,, ,, ..	Jiran ..	(3,000)	....
	8th ,, ,, ..	Dokat ..	(2,000)	....
	12th ,, ,, ..	Jiran ..	2,350	1·051
	13th ,, ,, ..	Dokat ..	900	1·053
	17th ,, ,, ..	Jiran ..	2,200	1·052
	19th ,, ,, ..	Tekat ..	1,500	1·050
	25th ,, ,, ..	,, ..	500	1·054
	28th ,, ,, ..	Jiran ..	2,100	1·054
	29th ,, ,, ..	Dokat ..	1,650	1·052
	30th ,, ,, ..	Tekat ..	500	1·058
	2nd Feb. 1912 ..	Jiran ..	(1,700)	....
	3rd ,, ,, ..	Dokat ..	1,250	1·050
	7th ,, ,, ..	Jiran ..	1,300	1·052
	8th ,, ,, ..	Dokat ..	1,750	1·049
		Total ..	40,250 =42,343 gms. (*). =93·37 lbs.	

* In this and succeeding tables, the weight in grammes of juice was determined by multiplying the number of c.c. by the average specific gravity, which was obtained by adding up and averaging all the specific gravity figures.

Notes on the tree.	Date.	Jiran, Dokat, or Tekat.	Volume c.c.	Specific gravity.
No. 2	4th Dec. 1911 ..	Jiran ..	200	....
2 years tapped male tree.	8th ,, ,, ..	,, ..	950	1·060
	9th ,, ,, ..	Dokat ..	600	....
	16th ,, ,, ..	Jiran ..	1,350	1·049
	17th ,, ,, ..	Dokat ..	750	1·049
	24th ,, ,, ..	Jiran ..	2,500	1·043
	25th ,, ,, ..	Dokat ..	(850)	....
	28th ,, ,, ..	Jiran ..	(1,900)	....
	29th ,, ,, ..	Dokat ..	(750)	....
	2nd Jan. 1912 ..	Jiran ..	(1,900)	....
	3rd ,, ,, ..	Dokat ..	(750)	....
	7th ,, ,, ..	Jiran ..	(1,900)	....
	8th ,, ,, ..	Dokat ..	900	1·050
	12th ,, ,, ..	Jiran ..	1,250	1·049
	13th ,, ,, ..	Dokat ..	550	1·047
	18th ,, ,, ..	Jiran ..	1,250	1·053
	19th ,, ,, ..	Dokat ..	600	1·050
	23rd ,, ,, ..	Jiran ..	(1,500)	....
	24th ,, ,, ..	Dokat ..	(1,050)	....
	28th ,, ,, ..	Jiran ..	1,750	1·051
	29th ,, ,, ..	Dokat ..	1,500	1·042
	30th ,, ,, ..	Tekat ..	500	1·048
	2nd Feb. 1912 ..	Jiran ..	1,250	1·051
	3rd ,, ,, ..	Dokat ..	1,250	1·042
	7th ,, ,, ..	Jiran ..	750	1·054
	8th ,, ,, ..	Dokat ..	1,950	1·043

Total ... 30,450

= 31,792 gms.
= 70·50 lbs.

Notes on the tree.	Date.	Jiran, Dokat, or Tekat.	Volume c.c.	Specific gravity.
No. 4	4th Dec. 1911 ..	Jiran ..	500	1·060
15 years tapped.	8th ,, ,, ..	,, ..	850	1·054
	9th ,, ,, ..	Dokat ..	750	1·052
	16th ,, ,, ..	Jiran ..	1,350	1·045
	17th ,, ,, ..	Dokat ..	750	1·046
	24th ,, ,, ..	Jiran ..	1,150	1·044
	25th ,, ,, ..	Dokat ..	(500)	....
	28th ,, ,, ..	Jiran ..	(900)	....
	29th ,, ,, ..	Dokat ..	(500)	....
	2nd Jan. 1912 ..	Jiran ..	(900)	....
	3rd ,, ,, ..	Dokat ..	(500)	....
	7th ,, ,, ..	Jiran ..	(900)	....
	8th ,, ,, ..	Dokat ..	250	1·056
	12th ,, ,, ..	Jiran ..	650	1·050
	13th ,, ,, ..	Dokat ..	100	....
	18th ,, ,, ..	Jiran ..	950	1·051
	19th ,, ,, ..	Dokat ..	400	1·054
	23rd ,, ,, ..	Jiran ..	(950)	....
	24th ,, ,, ..	Dokat ..	(450)	....
	28th ,, ,, ..	Jiran ..	950	1·049
	29th ,, ,, ..	Dokat ..	No pot.	
	2nd Feb. 1912 ..	Jiran ..	900	1·046
	3rd ,, ,, ..	Dokat ..	1,000	1·039
	7th ,, ,, ..	Jiran ..	750	1·043
	8th ,, ,, ..	Dokat ..	(750)	....
		Total ..	17,650 =18,532 gms. =40·77 lbs.	

Notes on the tree.	Date.	Jiran, Dokat, or Tekat.	Volume c.c.	Specific gravity.
No. 5	4th Dec. 1911 ..	Jiran ..	850	1·062
10 years tapped.	8th ,, ,, ..	,, ..	1,350	1·060
	9th ,, ,, ..	Dokat ..	1,000	1·062
	16th ,, ,, ..	Jiran ..	1,850	1·057
	17th ,, ,, ..	Dokat ..	1,000	1·056
	24th ,, ,, ..	Jiran ..	2,500	1·053
	25th ,, ,, ..	Dokat ..	(1,650)	....
	28th ,, ,, ..	Jiran ..	(2,850)	....
	29th ,, ,, ..	Dokat ..	(2,000)	....
	2nd Jan. 1912 ..	Jiran ..	(3,000)	....
	3rd ,, ,, ..	Dokat ..	(2,150)	....
	7th ,, ,, ..	Jiran ..	(3,100)	....
	8th ,, ,, ..	Dokat ..	2,300	1·048
	12th ,, ,, ..	Jiran ..	3,200	1·046
	13th ,, ,, ..	Dokat ..	1,350	1·050
	18th ,, ,, ..	Jiran ..	3,500	1·053
	19th ,, ,, ..	Dokat ..	2,450	1·047
	23rd ,, ,, ..	Jiran ..	(3,300)	....
	24th ,, ,, ..	Dokat ..	(2,700)	....
	25th ,, ,, ..	Tekat ..	600	1·056
	28th ,, ,, ..	Jiran ..	3,050	1·052
	29th ,, ,, ..	Dokat ..	3,000	1·046
	30th ,, ,, ..	Tekat ..	1,000	1·054
	2nd Feb. 1912 ..	Jiran ..	2,750	1·052
	3rd ,, ,, ..	Dokat ..	1,600	1·047
	7th ,, ,, ..	Jiran ..	1,750	1·056
	8th ,, ,, ..	Dokat ..	2,500	1·049
		Total ..	58,350 = 61,267 gms. = 134·78 lbs.	

Notes on the trees.	Date.	Jiran, Dokat, or Tekat.	Volume c. c.	Specific gravity.
No. 7 13 years tapped female.	4th Dec. 1911 ..	Jiran ..	900	1·053
	8th ,, ,, ..	,, ..	(1,100)	....
	9th ,, ,, ..	Dokat ..	(800)	....
	16th ,, ,, ..	Jiran ..	1,300	1·061
	17th ,, ,, ..	Dokat ..	800	1·060
	24th ,, ,, ..	Jiran ..	2,200	1·053
	25th ,, ,, ..	Dokat ..	(2,000)	....
	28th ,, ,, ..	Jiran ..	(2,300)	....
	29th ,, ,, ..	Dokat ..	(2,000)	....
	2nd Jan. 1912 ..	Jiran ..	(2,300)	....
	3rd ,, ,, ..	Dokat ..	(1,800)	....
	7th ,, ,, ..	Jiran ..	(3,200)	....
	8th ,, ,, ..	Dokat ..	2,650	1·050
	9th ,, ,, ..	Tekat ..	650	1·059
	12th ,, ,, ..	Jiran ..	3,800	1·053
	13th ,, ,, ..	Dokat ..	2,000	1·052
	17th ,, ,, ..	Jiran ..	3,250	1·053
	18th ,, ,, ..	Dokat ..	3,850	1·048
	19th ,, ,, ..	Tekat ..	2,100	1·051
	23rd ,, ,, ..	Jiran ..	(3,500)	....
	24th ,, ,, ..	Dokat ..	(3,500)	....
	25th ,, ,, ..	Tekat ..	800	1·057
	28th ,, ,, ..	Jiran ..	3,750	1·052
	29th ,, ,, ..	Dokat ..	4,150	1·048
	30th ,, ,, ..	Tekat ..	1,500	1·053
	2nd Feb. 1912 ..	Jiran ..	3,200	1·049
	3rd ,, ,, ..	Dokat ..	3,400	1·046
	7th ,, ,, ..	Jiran ..	2,600	1·054
	8th ,, ,, ..	Dokat ..	3,250	1·051
		Total ..	68,650 =72,285 gms. =159·03 lbs.	

Notes on the tree.	Date.	Jiran, Dokat, or Tekat.	Volume c. c.	Specific gravity.
No. 8 10 years tapped.	4th Dec. 1911 ..	Jiran ..	1,850	1·054
	8th ,, ,, ..	,, ..	1,500	1·050
	9th ,, ,, ..	Dokat ..	1,050	1·050
	16th ,, ,, ..	Jiran ..	1,750	1·041
	17th ,, ,, ..	Dokat ..	600	1·046
	24th ,, ,, ..	Jiran ..	1,750	1·039
	25th ,, ,, ..	Dokat ..	(850)	....
	28th ,, ,, ..	Jiran ..	(1,700)	....
	29th ,, ,, ..	Dokat ..	(950)	....
	2nd Jan. 1912 ..	Jiran ..	(1,700)	....
	3rd ,, ,, ..	Dokat ..	(950)	....
	8th ,, ,, ..	Jiran ..	1,650	1·038
	9th ,, ,, ..	Dokat ..	1,000	1·038
	13th ,, ,, ..	Jiran ..	1,350	1·035
	14th ,, ,, ..	Dokat ..	(1,100)	....
	19th ,, ,, ..	Jiran ..	1,450	1·039
	20th ,, ,, ..	Dokat ..	(1,100)	....
	24th ,, ,, ..	Jiran ..	(1,400)	....
	25th ,, ,, ..	Dokat ..	1,250	1·038
	26th ,, ,, ..	Tekat ..	200	....
	29th ,, ,, ..	Jiran ..	1,050	1·038
	30th ,, ,, ..	Dokat ..	1,050	1·042
	3rd Feb. 1912 ..	Jiran ..	1,450	1·040
	4th ,, ,, ..	Dokat	(1,450)	....
	8th ,, ,, ..	Jiran ..	800	1·039
	9th ,, ,, .. 10th ,, ,, ..	Owing to rain no juice was collected.	....	....
		Total ..	30,150 =31,356 gms. =68·98 lbs.	

Notes on the tree.	Date.	Jiran, Dokat, or Tekat.	Volume c.c.	Specific gravity.
No. 9 14 years tapped.	4th Dec. 1911 ..	Jiran ..	250	....
	8th ,, ,, ..	,, ..	750	1·070
	9th ,, ,, ..	Dokat ..	700	1·064
	16th ,, ,, ..	Jiran ..	1,850	1·058
	17th ,, ,, ..	Dokat ..	900	1·058
	24th ,, ,, ..	Jiran ..	3,000	1·049
	25th ,, ,, ..	Dokat ..	(2,100)	....
	28th ,, ,, ..	Jiran ..	(3,250)	....
	29th ,, ,, ..	Dokat ..	(2,300)	....
	2nd Jan. 1912 ..	Jiran ..	(3,250)	....
	3rd ,, ,, ..	Dokat ..	(2,300)	....
	8th ,, ,, ..	Jiran ..	3,500	1·053
	9th ,, ,, ..	Dokat ..	2,500	1·047
	13th ,, ,, ..	Jiran ..	2,550	1·049
	14th ,, ,, ..	Dokat ..	(2,300)	....
	19th ,, ,, ..	Jiran ..	4,000	1·050
	20th ,, ,, ..	Dokat ..	(3,250)	....
	24th ,, ,, ..	Jiran ..	(4,000)	....
	25th ,, ,, ..	Dokat ..	3,750	1·041
	26th ,, ,, ..	Tekat ..	750	1·056
	29th ,, ,, ..	Jiran ..	2,900	1·052
	30th ,, ,, ..	Dokat ..	3,150	1·045
	3rd Feb. 1912 ..	Jiran ..	2,850	1·050
	4th ,, ,, ..	Dokat ..	(3,100)	....
	8th ,, ,, ..	Jiran ..	4,250	1·041
	9th ,, ,, 10th ,, ,,	Owing to rain no juice was collected.	....	....
		Total ..	63,500 = 66,800 gns = 147·29 lbs	

Notes on the tree.	Date.	Jiran, Dokat, or Tekat.	Volume c.c.	Specific gravity.
No. 10 14 years tapped.	4th Dec. 1911 ..	Jiran ..	300	1·052
	8th ,, ,, ..	,, ..	700	1·056
	9th ,, ,, ..	Dokat ..	800	1·044
	16th ,, ,, ..	Jiran ..	1,350	1·043
	17th ,, ,, ..	Dokat ..	950	1·041
	24th ,, ,, ..	Jiran ..	1,700	1·041
	25th ,, ,, ..	Dokat ..	(1,000)	....
	28th ,, ,, ..	Jiran ..	(1,750)	....
	29th ,, ,, ..	Dokat ..	(1,000)	....
	2nd Jan. 1912 ..	Jiran ..	(1,800)	....
	3rd ,, ,, ..	Dokat ..	(1,000)	....
	8th ,, ,, ..	Jiran ..	1,800	1·044
	9th ,, ,, ..	Dokat ..	1,000	1·047
	13th ,, ,, ..	Jiran ..	1,750	1·046
	14th ,, ,, ..	Dokat ..	(1,600)	....
	19th ,, ,, ..	Jiran ..	2,000	1·047
	20th ,, ,, ..	Dokat ..	(1,800)	....
	24th ,, ,, ..	Jiran ..	(2,200)	....
	25th ,, ,, ..	Dokat ..	1,900	1·043
	26th ,, ,, ..	Tekat ..	700	1·050
	29th ,, ,, ..	Jiran ..	1,500	1·050
	30th ,, ,, ..	Dokat ..	1,550	1·045
	3rd Feb. 1912 ..	Jiran ..	1,000	1·053
	4th ,, ,, ..	Dokat ..	(1,000)	....
	8th ,, ,, ..	Jiran ..	1,250	1·052
	9th ,, ,, 10th ,, ,,	Owing to rain no juice was collected.	....	....
		Total ..	33,400 = 35,070 gms. = 77·32 lbs.	

Notes on the tree.	Date.	Jiran, Dokat, or Tekat.	Volume c.c.	Specific gravity.
No. 12 16 years tapped male tree.	4th Dec. 1911 ..	Jiran ..	1,000	1·060
	9th ,, ,, ..	,, ..	1,500	1·052
	16th ,, ,, ..	,, ..	2,850	1·047
	17th ,, ,, ..	Dokat ..	1,400	1·048
	24th ,, ,, ..	Jiran ..	2,950	1·043
	25th ,, ,, ..	Dokat ..	(1,350)	....
	28th ,, ,, ..	Jiran ..	(3,200)	....
	29th ,, ,, ..	Dokat ..	(1,600)	....
	2nd Jan. 1912 ..	Jiran ..	(3,300)	....
	3rd ,, ,, ..	Dokat ..	(1,600)	....
	7th ,, ,, ..	Jiran ..	(3,300)	....
	8th ,, ,, ..	Dokat ..	1,300	1·047
	12th ,, ,, ..	Jiran ..	3,450	1·042
	13th ,, ,, ..	Dokat ..	2,650	1·039
	17th ,, ,, ..	Jiran ..	2,500	1·047
	18th ,, ,, ..	Dokat ..	2,500	1·042
	19th ,, ,, ..	Tekat ..	1,450	1·049
	23rd ,, ,, ..	Jiran ..	(2,400)	....
	24th ,, ,, ..	Dokat ..	(2,200)	....
	25th ,, ,, ..	Tekat ..	250	....
	28th ,, ,, ..	Jiran ..	2,200	1·050
	29th ,, ,, ..	Dokat ..	1,900	1·044
	30th ,, ,, ..	Tekat ..	250	1·054
	2nd Feb. 1912 ..	Jiran ..	2,000	1·050
	3rd ,, ,, ..	Dokat ..	1,850	1·044
	7th ,, ,, ..	Jiran ..	1,250	1·055
	8th ,, ,, ..	Dokat ..	1,085	1·043
		Total ..	54,050	
			= 56,752 gms. = 125·13 lbs.	

Notes on the tree.	Date.	Jiran, Dokat, or Tekat.	Volume c.c.	Specific gravity.
No. 13 12 years tapped.	4th Dec. 1911 ..	Jiran ..	100	....
	8th " " ..	" ..	300	1·070
	16th " " ..	" ..	1,050	1·061
	17th " " ..	Dokat ..	550	1·059
	24th " " ..	Jiran ..	1,650	1·054
	25th " " ..	Dokat ..	(1,400)	....
	28th " " ..	Jiran ..	(2,100)	....
	29th " " ..	Dokat ..	(1,800)	....
	2nd Jan. 1912 ..	Jiran ..	(2,300)	....
	3rd " " ..	Dokat ..	(2,000)	....
	7th " " ..	Jiran ..	(2,400)	....
	8th " " ..	Dokat ..	2,250	1·048
	12th " " ..	Jiran ..	2,550	1·053
	13th " " ..	Dokat ..	1,000	1·053
	17th " " ..	Jiran ..	2,250	1·052
	18th " " ..	Dokat ..	2,500	1·048
	19th " " ..	Tekat ..	1,000	1·053
	23rd " " ..	Jiran ..	(2,300)	....
	24th " " ..	Dokat ..	(2,250)	....
	25th " " ..	Tekat ..	200	....
	28th " " ..	Jiran ..	2,400	1·053
	29th " " ..	Dokat ..	2,000	1·050
	30th " " ..	Tekat ..	500	1·056
	2nd Feb. 1912 ..	Jiran ..	2,000	1·052
	3rd " " ..	Dokat ..	1,500	1·050
	7th " " ..	Jiran ..	1,300	1·052
	8th " " ..	Dokat ..	2,000	1·051
		Total ..	43,650	
			= 46,010 gms.	
			= 101·45 lbs.	

Notes on the tree.	Date.	Jiran, Dokat, or Tekat.	Volume c.c.	Specific gravity.
No. 14 16 years tapped male tree.	8th Dec. 1911 ..	Jiran ..	400	1·070
	16th ,, ,, ..	,, ..	1,250	1·058
	17th ,, ,, ..	Dokat ..	900	1·054
	24th ,, ,, ..	Jiran ..	2,000	1·048
	25th ,, ,, ..	Dokat ..	(1,000)	....
	28th ,, ,, ..	Jiran ..	(2,300)	....
	29th ,, ,, ..	Dokat ..	(1,100)	....
	2nd Jan. 1912 ..	Jiran ..	(2,450)	....
	3rd ,, ,, ..	Dokat ..	(1,200)	....
	7th ,, ,, ..	Jiran ..	(2,500)	....
	8th ,, ,, ..	Dokat ..	1,150	1·050
	12th ,, ,, ..	Jiran ..	2,600	1·045
	13th ,, ,, ..	Dokat ..	1,250	1·046
	18th ,, ,, ..	Jiran ..	2,800	1·048
	19th ,, ,, ..	Dokat ..	1,700	1·047
	23rd ,, ,, ..	Jiran ..	(2,300)	....
	24th ,, ,, ..	Dokat ..	(1,750)	....
	25th ,, ,, ..	Tekat ..	600	1·052
	28th ,, ,, ..	Jiran ..	1,950	1·051
	29th ,, ,, ..	Dokat ..	No pot.	
	30th ,, ,, ..	Tekat ..	650	1·052
	2nd Feb. 1912 ..	Jiran ..	1,900	1·047
	3rd ,, ,, ..	Dokat ..	1,800	1·046
	7th ,, ,, ..	Jiran ..	1,000	1·052
	8th ,, ,, ..	Dokat ..	1,800	1·049
		Total ..	38,350 = 40,310 gms. = 88·86 lbs.	

Notes on the tree.	Date.	Jiran, Dokat, or Tekat.	Volume c.c.	Specific gravity.
No. 15 15 years tapped.	4th Dec. 1911 ..	Jiran ..	200	....
	8th ,, ,, ..	,, ..	350	1·058
	9th ,, ,, ..	Dokat ..	....	....
	16th ,, ,, ..	Jiran ..	950	1·050
	17th ,, ,, ..	Dokat ..	....	....
	24th ,, ,, ..	Jiran ..	1,000	1·045
	25th ,, ,, ..	Dokat ..	(500)	....
	28th ,, ,, ..	Jiran ..	(1,050)	....
	29th ,, ,, ..	Dokat ..	(600)	....
	2nd Jan. 1912 ..	Jiran ..	(1,100)	....
	3rd ,, ,, ..	Dokat ..	(600)	....
	8th ,, ,, ..	Jiran ..	1,100	1·045
	9th ,, ,, ..	Dokat ..	500	1·050
	13th ,, ,, ..	Jiran ..	1,000	1·044
	14th ,, ,, ..	Dokat ..	(600)	....
	19th ,, ,, ..	Jiran ..	1,150	1·045
	20th ,, ,, ..	Dokat ..	(600)	....
	25th ,, ,, ..	Jiran ..	1,150	1·039
	26th ,, ,, ..	Dokat ..	250	1·047
	29th ,, ,, ..	Jiran ..	950	1·044
	30th ,, ,, ..	Dokat ..	(700)	....
	3rd Feb. 1912 ..	Jiran ..	700	1·045
	4th ,, ,, ..	Dokat ..	(600)	....
	8th ,, ,, ..	Jiran ..	800	1·046
	9th ,, ,, 10th ,, ,,	Owing to rain no juice was collected.	....	....
		Total ..	17,450 = 18,250 gms. = 40·24 lbs.	

Notes on the tree.	Date.	Jiran, Dokat, or Tekat.	Volume c.c.	Specific gravity.
No. 17 15 years tapped.	4th Dec. 1911 ..	Jiran ..	250	....
	8th ,, ,, ..	,, ..	750	1·058
	9th ,, ,, ..	Dokat ..	750	1·058
	16th ,, ,, ..	Jiran ..	1,400	1·053
	17th ,, ,, ..	Dokat ..	500	1·056
	24th ,, ,, ..	Jiran ..	1,750	1·049
	25th ,, ,, ..	Dokat ..	(500)	....
	28th ,, ,, ..	Jiran ..	(1,800)	....
	29th ,, ,, ..	Dokat ..	(500)	....
	2nd Jan. 1912 ..	Jiran ..	(1,800)	....
	3rd ,, ,, ..	Dokat ..	(500)	....
	7th ,, ,, ..	Jiran ..	(1,800)	....
	8th ,, ,, ..	Dokat ..	550	1·057
	12th ,, ,, ..	Jiran ..	1,800	1·050
	13th ,, ,, ..	Dokat ..	750	1·054
	18th ,, ,, ..	Jiran ..	1,350	1·056
	19th ,, ,, ..	Dokat ..	750	1·056
	24th ,, ,, ..	Jiran ..	(1,550)	....
	25th ,, ,, ..	Dokat ..	(1,100)	....
	28th ,, ,, ..	Jiran ..	1,750	1·051
	29th ,, ,, ..	Dokat ..	1,500	1·046
	2nd Feb. 1912 ..	Jiran ..	2,200	1·044
	3rd ,, ,, ..	Dokat ..	1,750	1·044
	7th ,, ,, ..	Jiran ..	1,000	1·049
	8th ,, ,, ..	Dokat ..	1,500	1·049
		Total ..	29,850	
			=31,361 gms. =69·23 lbs.	

Notes on the tree.	Date.	Jiran, Dokat, or Tekat.	Volume c.c.	Specific gravity.
No. 19	4th Dec. 1911 ..	Jiran ..	250	....
11 years tapped.	8th ,, ,, ..	,, ..	(700)	....
	16th ,, ,, ..	,, ..	1,150	1·047
	17th ,, ,, ..	Dokat ..	950	1·045
	24th ,, ,, ..	Jiran ..	1,600	1·042
	25th ,, ,, ..	Dokat ..	(1,050)	....
	28th ,, ,, ..	Jiran ..	(1,650)	....
	29th ,, ,, ..	Dokat ..	(1,100)	....
	2nd Jan. 1912 ..	Jiran ..	(1,700)	....
	3rd ,, ,, ..	Dokat ..	(1,100)	....
	7th ,, ,, ..	Jiran ..	(1,700)	....
	8th ,, ,, ..	Dokat ..	1,150	1·046
	12th ,, ,, ..	Jiran ..	1,750	1·043
	13th ,, ,, ..	Dokat ..	750	1·046
	18th ,, ,, ..	Jiran ..	1,900	1·045
	19th ,, ,, ..	Dokat ..	1,900	1·040
	23rd ,, ,, ..	Jiran ..	(1,600)	....
	24th ,, ,, ..	Dokat ..	(1,600)	....
	28th ,, ,, ..	Jiran ..	1,250	1·049
	29th ,, ,, ..	Dokat ..	1,400	1·042
	2nd Feb. 1912 ..	Jiran ..	800	1·048
	3rd ,, ,, ..	Dokat ..	750	1·046
	7th ,, ,, ..	Jiran ..	500	1·052
	8th ,, ,, ..	Dokat ..	Not tapped again till after the 10th.	
		Total ..	28,300	
			= 29,563 gms. = 65·26 lbs.	

Notes on the tree.	Date.	Jiran, Dokat, or Tekat.	Volume c.c.	Specific gravity.	Direct reading.	Sucrose per cent.	Reducing sugar per cent.	Total sugar per cent.
No. 11 13 years tapped.	4-12-11	Jiran ...	1,150	1·052	46·2	11·44	0·12	11·56
	8-12-11	Jiran ...	1,600	1·049	42·8	10·63	0·25	10·88
	9-12-11	Dokat ...	1,350	1·048	37·6	9·34	0·76	10·10
	16-12-11	Jiran ...	2,750	1·044	35·1	8·76	0·70	9·46
	17-12-11	Dokat ...	1,750	1·042	31·9	7·97	1·16	9·13
	24-12-11	Jiran ...	2,600	1·041	35·0	8·76	0·34	9·10
	25-12-11	Dokat ...	2,200	1·038	31·1	7·80	0·84	8·64
	28-12-11	Jiran ...	(3,050)	...	...	...	...	...
	29 12 11	Dokat ...	2,000	1·038	29·6	7·43	1·25	8·68
	30-12 11	Tekat ...	650	1·048	36·5	9·05	1·90	10·95
	2-1-12	Jiran ...	3,500	1·038	33·2	8·33	0·46	8·79
	3-1-12	Dokat ...	2,200	1·044	26·1	6·53	2·23	8·76
	4-1-2	Tekat ...	(500)	...	...	...	...	...
	7-1-12	Jiran ...	(3,300)	...	...	...	...	...
	8-1-12	Dokat .	2,700	1·035	29·9	7·50	0·58	8·08
	12-1-12	Jiran ...	3,050	1·039	31·4	7·86	0·42	8·28
	13-1-12	Dokat ...	750	1·045	22·6	5·63	3·80	9·43
	18-1-12	Jiran ...	3,850	1·042	30·7	7·67	0 94	8·61
	19-1-12	Dokat ...	2,950	1·036	25·7	6·46	1·00	7·46
	23-1-12	Jiran ...	(3,300)	...	...	...	...	...
	24-1-12	Dokat ...	(2,700)	...	...	...	...	...
	25-1-12	Tekat ...	250	...	19·8	4·95	4·60	9·55
	28-1-12	Jiran ...	2,700	1,044	29·0	7·24	1·50	8·74
	29-1-12	Dokat ...	2,400	1·038	23·5	5·90	1·62	7·52
	30-1-12	Tekat ...	500	1·048	23·3	5·79	3·22	9·01
	2-2-12	Jiran ...	1,900	1·044	32·9	8·21	1·47	9·68
	3-2-12	Dokat ...	1,600	1·041	27·1	6·78	1·37	8·15
	7-2-12	Jiran . .	1,250	1·049	40·0	9·93	0·83	10·76
	8-2-12	Dokat ...	1,600	1·042	27·0	6·75	1·74	8·49
		Total ...	62,100					
			= 64,770 gms. = 142·82 lbs.					

Notes on the tree.	Date.	Jiran, Dokat, or Tekat.	Volume c.c.	Specific gravity.	Direct reading.	Sucrose per cent.	Reducing sugar per cent.	Total sugar per cent.
No. 16 1 year tapped.	4-12-11	Jiran ..	900	1·062	...	...	...	...
	8-12-11	Jiran ..	1,000	1·062	...	...	...	...
	9-12-11	Dokat ...	550	1·062	...	...	...	...
	16-12-11	Jiran ..	2,000	1·057	46·1	11·36	0 87	12·23
	17-12-11	Dokat ...	1,250	1·054	40·0	9·88	1·35	11·23
	24-12-11	Jiran ...	1,250	1·050	43·7	10 84	0·32	11·16
	25-12-11	Dokat ...	2,200	1·048	42 0	10·44	0·54	10·98
	29-12-11	Jiran ...	3,000	1·050	42·7	10·59	0·64	11·23
	30-12-11	Dokat ...	2,750	1·046	36·8	9·16	1·03	10·19
	3-1-12	Jiran ...	3,500	1·048	38·8	9·64	1·14	10·78
	4-1-12	Dokat ...	(2,400)	...	...	...	...	...
	8-1-12	Jiran ...	3,550	1·049	38·6	9·59	0·78	10·37
	9-1-12	Dokat ...	2,000	1 048	36·3	9·02	0 83	9·85
	13-1-12	Jiran ...	2,400	1·043	24·8	6·19	3·80	9 99
	14-1-12	Dokat ...	(1,700)	...	...	...	...	...
	19-1-12	Jiran ...	3,900	1·047	27·6	6·87	2·25	9 12
	20-1-12	Dokat ...	(3,100)	...	...	...	...	...
	24-1-12	Jiran ...	(3,600)	...	...	...	...	...
	25-1-12	Dokat ...	3,500	1·044	33·5	8·36	0·94	9·30
	26-1-12	Tekat ...	2,000	1·047	37·9	9·43	0 99	10·42
	29-1-12	Jiran ...	3,250	1·049	41·4	10·28	0·51	10·79
	30-1-12	Dokat ...	2,100	1·047	34·6	8·61	1·74	10·35
	3-2-12	Jiran ...	2,850	1·050	40·3	10·00	0·73	10·73
	4-2-12	Dokat ...	(2,100)	...	...	...	...	...
	8-2-12	Jiran ...	2,650	1·054	43·0	10·63	0·95	11·58
		Total ...	60,000 c.c.					
			= 62,922 gms = 138·90 lbs.					

Notes on the tree.	Date.	Jiran, Dokat or Tekat.	Volume c.c.	Specific gravity.	Direct reading.	Sucrose per cent.	Reducing sugar per cent.	Total sugar per cent.
No. 20 14 years tapped.	4-12-11	Jiran ...	500	1·064	57·0	13·95	0·20	14·15
	8-12-11	Jiran ...	900	1·058	51·2	12·60	0·33	12·99
	9-12-11	Dokat...	850	1·056	42·4	10·46	1·14	11·60
	16-12-11	Jiran ...	1,750	1·050	41·3	10·24	0·68	10·92
	17-12-11	Dokat...	1,050	1·049	37·9	9·41	1·10	10·51
	24-12-11	Jiran ...	3,500	1·048	42·0	10·44	0·22	10·66
	25-12-11	Dokat ..	2,750	1·042	35·7	8·92	0·60	9·52
	28-12-11	Jiran ...	(3,400)	...	...	...	...	...
	29-12-11	Dokat...	2,250	1·043	36·0	8·99	1·00	9·99
	30-12-11	Tekat ...	750	1·052	43·5	10·77	1·43	12·20
	2-1-12	Jiran ...	3,350	1·045	38·9	9·69	0·66	10·35
	3-1-12	Dokat...	2,500	1·049	33·7	8·37	1·52	9·89
	7-1-12	Jiran ...	(3,700)	...	...	...	...	...
	8-1-12	Dokat...	3,250	1·044	36·0	8·98	0·58	9·56
	9-1-12	Tekat ...	1,000	1·054	44·8	11·08	0·74	11·82
	12-1-12	Jiran ...	4,000	1·048	39·6	9·84	1·71	11·55
	13-1-12	Dokat...	1,550	1·049	39·8	9·88	1·71	11·59
	17-1-12	Jiran ...	3,100	1·050	43·4	10·76	0·59	11·35
	18-1-12	Dokat...	3,700	1·046	34·0	8·47	1·24	9·71
	19-1-12	Tekat ...	1,750	1·050	34·6	8·58	1·88	10·46
	23-1-12	Jiran ...	(3,100)	...	...	...	...	...
	24-1-12	Dokat...	(3,000)	...	...	...	...	...
	25-1-12	Tekat ...	650	1·054	33·8	8·35	3·73	12·08
	28-1-12	Jiran ...	3,050	1·052	44·1	10·92	0·48	11·40
	29-1-12	Dokat...	2,300	1·047	35·1	8·73	1·50	10·23
	30-1-12	Tekat ...	500	1·057	33·9	8·35	3·16	11·51
	2-2-12	Jiran ...	2,850	1·049	30·6	7·60	3·22	10·82
	3-2-12	Dokat...	2,200	1·047	33·2	8·26	1·47	9·73
	7-2-12	Jiran ...	1,600	1·052	42·0	10·40	1·19	11·59
	8-2-12	Dokat...	2,000	1·049	37·2	9·24	1·13	10·37

Total ... 66,850
= 70,190 gms.
= 154·77 lbs.

Notes on the tree.	Date.	Jiran, Dokat or Tekat.	Volume c.c.	Specific gravity.	Direct reading.	Sucrose per cent.	Reducing sugar per cent.	Total sugar per cent.
No. 3 3 years tapped.	4-12-11	Jiran ...	850	1·044	...	...	...	...
	8-12-11	,, ..	1,750	1·045	...	...	...	...
	9-12-11	Dokat ...	1,300	1·046	...	...	...	...
	16-12-11	Jiran ...	2,050	1·040	33·6	8·48	0·35	8·83
	17-12-11	Dokat ...	1,600	1·042	29·3	7·32	1·30	8·62
	24-12-11	Jiran ...	2,000	1·044	39·5	9·85	0·37	10·22
	25-12-11	Dokat ...	1,650	1·043	36·8	9·19	0·85	10·04
	28-12-11	Jiran ...	(2,250)	...	...	...	...	...
	29-12-11	Dokat ...	1,550	1·040	31·0	7·76	1·10	8·86
	30-12-11	Tekat ...	750	1·047	37·0	9·20	1·70	10·90
	2-1-12	Jiran ...	2,500	1·042	36·6	9·15	0·52	9·67
	3-1-12	Dokat ...	1,200	1·039	26·5	6·64	1·90	8·54
	7-1-12	Jiran ...	(2,350)	...	...	...	...	...
	8-1-12	Dokat ...	1,450	1·045	34·5	8·60	0·96	9·56
	12-1-12	Jiran ...	2,200	1·044	35·1	8·76	0·64	9·40
	13-1-12	Dokat ...	800	1·046	30·8	7·67	3·04	10·71
	17-1-12	Jiran ...	1,750	1·044	38·0	9·48	0·42	9·90
	18-1-12	Dokat ...	2,250	1·040	27·7	6·94	1·47	8·41
	19-1-12	Tekat ...	1,000	1·044	28·9	7·21	1·88	9·09
	22-1-12	Jiran ...	(1,750)	...	...	...	...	...
	23-1-12	Dokat ...	(1,000)	...	...	...	...	...
	24-1-12	Tekat ...	(500)	...	...	...	...	...
	28-1-12	Jiran ...	(1,625)	...	...	...	...	...
	29-1-12	Dokat ...	1,500	1·039	29·3	7·35	1·03	8·38
	30-1-12	Tekat ...	700	1·046	25·7	6·40	3·22	9·62
	2-2-12	Jiran ...	1,500	1·046	38·3	9·54	0·83	10·37
	3-2-12	Dokat ...	1,450	1·040	29·5	7·39	0·83	8·22
	7-2-12	Jiran ...	750	1·050	43·0	10·67	1·05	11·72
	8-2-12	Dokat ...	1,350	1·045	32·8	8·18	1·12	9·30

Total ... 44,325
= 46,275 gms.
= 102·04 lbs.

Trees Nos. 6 and 18 are omitted from the tables, as 6 was abandoned early in the season by the tappers, and only so few measurements of No. 18 were made that they could not form a really good guide as to the annual yield of the tree. Of the remaining 18 trees the average yield of juice per tree comes out at 101·15 lbs.

It must here be remembered that juice was only collected from these trees for the purpose of the experiment from December 4th till February 8th. The normal date sugar season however extends from about the second week in November till the first week in March.

In the period under experiment only about 28 collections of juice on an average were taken from each tree. A full tapping period would include about 45 collections of juice per tree. In order to calculate from our figures the yield of juice per tree per season one cannot simply multiply the figure found by 45/28 for the following reasons. In the first place, the yields during November and the later part of February are not so high as in December and January. Further, we must allow for rainy or cloudy weather which prevents collection of juice. Allowing for these facts, one may yet safely add 1/3 to the figures obtained above, in order to get the yield of juice per tree per season.

In this way we arrive at an average of juice per tree per season of 134·87 lbs.

The garden in which these 20 trees were situated is considered by the author to be distinctly below the average of the gardens in the district. This opinion has been formed as a result of about 2,000 individual measurements of trees throughout the district.

Measurements have been made also at Jessore town, Jhenidah, Kaliganj, Chowgachha and Tarpur, and in the villages for some miles around these centres and around Kotechandpur. These occasional measurements of individual trees cannot of course be used as a basis for calculating the annual yield of juice per tree. Around Jhenidah, the date cultivation is very poor and yields seem very low.

Near Jessore town the yields are larger than in other places, and in village Khartalar some very fine trees exist. This particular village was visited first on December 26th and 27th. In consequence of the high yields it was thought worth while visiting the garden again in early February.

The statement below shows the yields recorded by us in one particularly good plantation in this village in December and again in February. The outstanding features of this garden were the exceptional thickness of the trees, and the excellent cultivation. It seems that 300 lbs. of juice per tree per season might be expected in this garden, *i.e.*, 37½ lbs. of gur.

The yields in all the other places mentioned appear to be much about the same.

In conclusion, the author considers that 170 lbs. of juice per tree per season may be taken as a fair average yield throughout the date sugar districts.

YIELDS OF DATE JUICE, KHARTALAR VILLAGE, JESSORE TOWN.

(Soil clayey and field well tilled. Trees 15′ × 15′.)

Date.	Years tapped.	Jiran, Dokat, or Tekat.	Volume c.c.	Specific gravity.
26th December 1911 ..	6	Jiran	600	1·066
	16	,,	4900	1·056
	16	,,	2750	1·061
	13	,,	2750	1·060
	15	,,	3400	1·056
	14	,,	4000	1·052
	12	,,	5500	1·053
	13	,,	1350	1·061
	13	,,	3350	1·062
	9	,,	2350	1·051
	13	,,	1100	1·070
	10	,,	3750	1·056
	12	,,	5750	1·056
	10	,,	2800	1·062
	13	,,	3650	1·056
	13	,,	2750	1·060
	13	,,	2350	1·060
	14	,,	5200	1·056

Date.	Years tapped.	Jiran, Dokat or Tekat.	Volume c. c.	Specific gravity.
27th December 1911..	4	Dokat	1750	1·042
	9	,,	900	1·052
	7	,,	2650	1·048
	11	,,	1100	1·067
	10	,,	2500	1·050
	12	,,	850	1·067
	6	,,	450	1·063
	14	,,	2500	1·060
	10	,,	1900	1·058
	13	,,	2250	1·053
	13	,,	2100	1·059
	13	,,	1950	1·059
	15	,,	800	1·060
	16	,,	1850	1·061
	13	,,	2200	1·057
	12	,,	3500	1·055
	16	,,	3250	1·054
	15	,,	3200	1·050
4th February 1912 ..	14	Jiran	4150	1·054
	12	,,	4500	1·050
	13	,,	3350	1·054
	15	,,	3000	1·050
	15	,,	2400	1·058
	15	,,	3750	1·046
	13	,,	2250	1·060
	15	,,	3100	1·050
	15	,,	2000	1·048
5th February 1912 ..	16	,,	6300	1.052
	10	,,	5500	1·054
	13	,,	6000	1·050
	10	,,	5250	1·053
	13	,,	4200	1·058
	11	,,	3000	1·061
	12	,,	1950	1·064
	7	,,	4200	1.054
	9	,,	3000	1·054
	4	,,	1650	1·055
	10	,,	2800	1·054
	13	,,	4750	1·054
	13	,,	3500	1·059
	15	Dokat	1750	1·060

Maximum daily yield of Juice per Tree.

The largest amount of juice observed from a single tree in one night was 6,600 c.c. or 15·25 lbs. near Kotechandpur. Other large yields were 14·30 lbs. near Kotechandpur and 14·61 lbs. at

Jessore. In order to get the total yield of juice in 24 hours one must add the amount of juice flowing during the day Measurements of this were not made, but it would probably be about 30 to 50% of the amount collected at night.

Variation in composition and yield of Juice at different periods during the Night.

We have already seen (p. 298) that jiran juice is of better quality than dokat juice, and further that commonly jiran juice is yielded in larger quantity than dokat. This in turn is better in quality than tekat juice and also its yield is much greater. It seemed of interest to determine if the yield of juice varied in its rate of flow and composition during a single night.

Accordingly during February 1911 certain trees were selected and their juice collected at various periods during the night, measured and analysed.

No. of trees.	Years tapped to date.	Jiran, Dokat or tekat.	Date of collection.	Period of collection.	Volume of juice c.c.	Sucrose gms. per 100 c.c.	Reducing sugars.
A	13	Jiran	16th Feb. 1911	5 to 6-15 P.M.	2075	17·75	1·04
		,,	16th ,, ,,	6-15 to 7-40 ,,	2075	13·95	0·65
		,,	16th ,, ,,	7-40 ,,	....	....	....
		,,	17th ,, ,,	5-30 A.M.	....	11·20	0·93
B	....	,,	16th ,, ,,	5 to 6-15 P.M.	....	15·50	0·53
				6-15 to 7-40 ,,	3700	13·90	0·34
		,,	16th ,, ,,	7-40 ,,	....	....	....
		,,	17th ,, ,,	5-30 A.M.	....	11·55	0·53
C	....	,,	18th ,, ,,	5 to 6-20 P.M.	500	14·50	1·25
		,,	18th ,, ,,	6-20 to 8-10 ,,	250	12·65	1·10
		,,	18th ,, ,,	8-10 ,,	....	....	....
		,,	19th ,, ,,	5-20 A.M.	1200	10·80	0·53
		,,	19th ,, ,,	5-20 ,,	200	9·20	0·65
				7 ,,	....	....	....
D	....	,,	18th ,, ,,	5 to 6-20 P.M.	500	13·45	1·05
		,,	18th ,, ,,	6-20 to 8-10 ,,	250	10·55	0·70
		,,	18th ,, ,,	8-10 ,,	....	....	....
		,,	19th ,, ,,	5-20 A.M.	1200	8·75	0·74
		,,	19th ,, ,,	5-20 to 7 ,,	200	7·50	0·63
5	12	Dokat	15th ,, ,,	5 to 6-30 P.M.	250	13·90	0·64
		,,	15th ,, ,,	6-30 ,,	....	....	....
		,,	16th ,, ,,	5-20 A.M.	3100	11·75	1·04
		,,	16th ,, ,,	5-20 ,,	....	....	....
				7-30 ,,	....	9·20	1·80
6	10	,,	15th ,, ,,	5 to 6-30 P.M.	200	11·63	1·28
		,,	15th ,, ,,	6-30 ,,	....	....	....
		,,	16th ,, ,,	5-20 A.M.	2100	8·70	1·73
		,,	16th ,, ,,	5-20 to 7-30 ,,	....	6·12	2·30

The tables shew that throughout the night there is a regular and rapid fall in the amount of cane-sugar in the juice. The reducing sugar has not shewn a corresponding increase. In fact in trees A, B, C and D yielding jiran juice, the reducing sugar has tended to decrease in proportion with the reduction of cane-sugar. In trees 5 and 6 yielding dokat juice, the amount of reducing sugar has increased to some extent with the decreasing content of cane-sugar.

It thus seems that the decrease in quality of the juice throughout the night is not entirely due to inversion, but the juice actually gets less and less concentrated.

In January and February 1912 the experiment was repeated on a single tree. This tree was in an isolated position being in an open space a good half mile from any other trees tapped for juice.

The only other differences between this and the above experiments were that in this case the juice was collected in an enamelled pot and further the tree had only been tapped on two or three occasions this season.

The cut surface was very clean in this case, and as will be seen a remarkably good juice was obtained. On the 17th and 18th January the juice collected contained only the merest trace of invert sugar certainly less than 0·05%.

Expt. No.	Date of collection.	Period of collection.	Volume of juice c.c.	Sucrose gms. per 100 c.c.	Reducing sugar.
1	17th January 1912 ..	4-30 to 6-15 P.M.	170	13·99	Trace.
	17th ,, ,, ..	6-30 to 8-15 ,,	160	13·86	,,
	17th ,, ,, ..	8-35 to 10-30 ,,	175	14·02	,,
	18th ,, ,, ..	10-45 P.M. to 6-30 A.M.	....	13·31	,,
2	6th February 1912 ..	4-50 to 6-15 P.M.	160	13·62	0·50
	6th ,, ,, ..	6-25 to 7-45 ,,	190	13·81	0·55
	6th ,, ,, ..	7-55 to 9-30 ,,	160	13·60	0·58

This experiment does not show the same steady decline in richness and quality of the juice as the former experiments did.

CHART NO. 5.

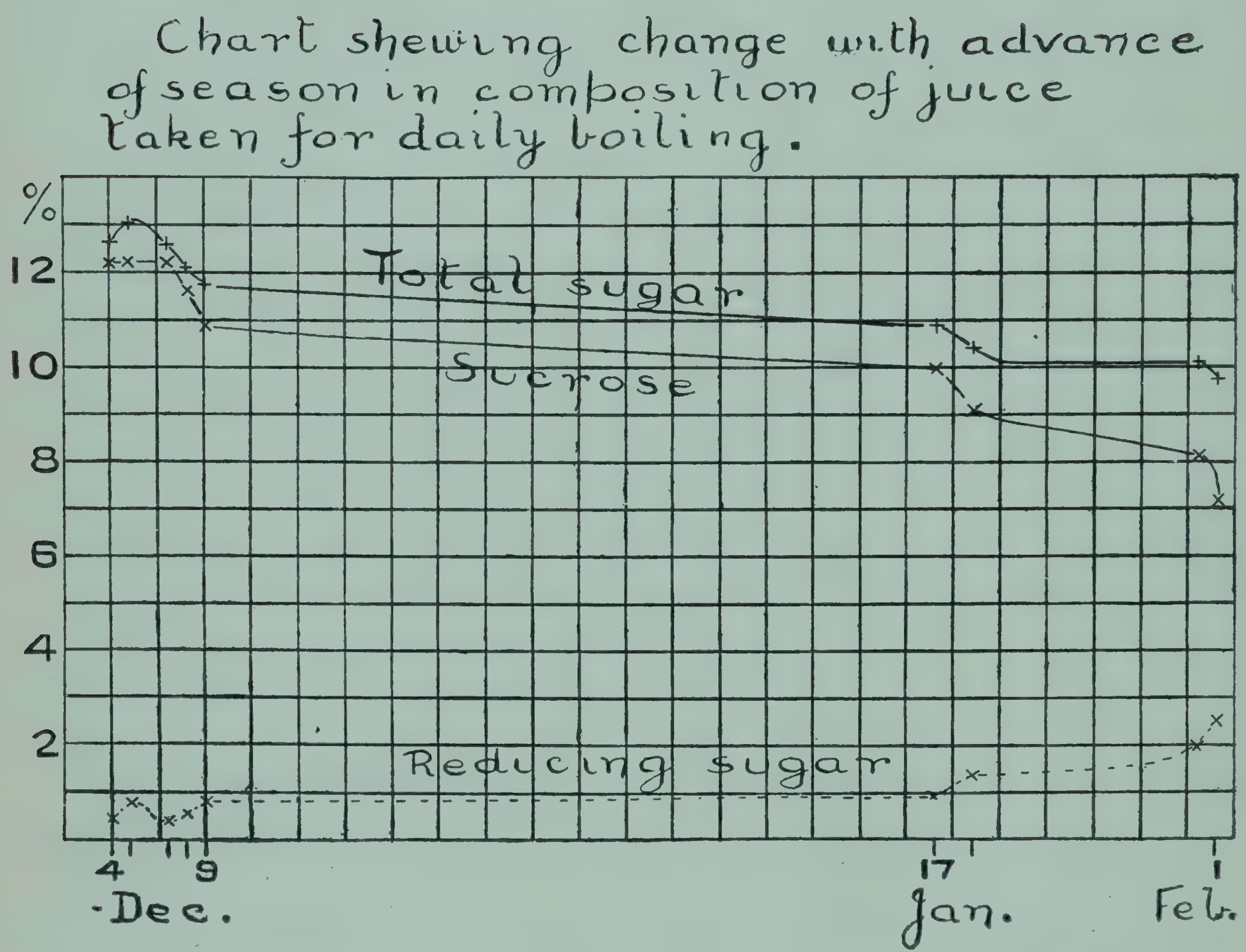


Chart shewing change with advance of season in composition of juice taken for daily boiling.
%
12
10
8
6
4
2
Total sugar
Sucrose
Reducing sugar
4
9
17
1
Dec.
Jan.
Feb.

Composition of the juice.

The tables and charts already given shew the analyses of a large number of juices. The connection between the amount of sugar in the juice and the yield of juice has already been referred to.

Throughout the season analyses have been made of the juice as it has been collected for the daily boilings. These analyses have been made at various places throughout the Jessore district and are collected together in the following table :—

Date.	Specific gravity.	Sucrose %.	Reducing sugar %.	Locality.
4th December 1911 ..	1·056	12·15	0·42	Garden No. 1, Kotechandpur.
5th ,, ,, ..	1·058	12·17	0·77	,, ,, 1, ,,
6th ,, ,, ..	1·049	10·50	1·03	,, ,, 2, ,,
7th ,, ,, ..	1·055	12·22	0·37	,, ,, 1, ,,
7th ,, ,, ..	1·053	10·38	0·70	,, ,, 2, ,,
8th ,, ,, ..	1·056	11·62	0·55	,, ,, 1, ,,
9th ,, ,, ..	1·054	10·85	0·85	,, ,, 1, ,,
11th ,, ,, ..	1·051	10·49	1·04	,, ,, 2, ,,
19th ,, ,, ..	1·059	11·80	1·55	Chowgachha.
20th ,, ,, ..	1·060	11·65	1·43	,,
22nd ,, ,, ..	1·053	11·16	0·69	Tarpur.
5th January 1912 ..	1·048	8·90	1·21	Jhenidah.
6th ,, ,, ..	1·049	9·87	1·03	Kaliganj.
16th ,, ,, ..	1·048	9·47	1·10	Sulemanpur.
16th ,, ,, ..	1·054	10·28	0·84	,,
17th , ,, ..	1·047	9·96	0·90	Garden 1, Kotechandpur.
19th ,, ,, ..	1·047	9·06	1·32	,, ,, ,,
21st ,, ,, ..	1·051	10·53	1·25	Maladharpur.
22nd ,, ,, ..	1·051	10·43	1·42	,,
23rd ,, ,, ..	1·048	8·70	1·72	,,
23rd ,, ,, ..	1·052	9·04	1·88	,,
23rd ,, ,, ..	1·054	9·73	2·50	,,
23rd ,, ,, ..	1·051	9·91	1·72	,,
24th ,, ,, ..	1·053	10·51	2·80	Bidyadharpur.
24th ,, ,, ..	1·047	9·21	3·22	,,
27th ,, ,, ..	1·054	10·90	1·02	Kotechandpur.
31st ,, ,, ..	1·047	8·11	1·97	Garden 1, Kotechandpur.
1st February ,, ..	1·043	7·15	2·54	,, ,, ,,

In garden No. 1 above it will be seen that analyses of the juice have been made at varying intervals throughout the season. In chart No. 5 these data are plotted in curves showing total sugar, sucrose and reducing sugar. These curves illustrate the excellent quality of the juice at the beginning of the season and shew how the glucose ratio rises as the season advances.

The table shows the results of the analysis of three different date juices side by side with an analysis of juice of red Mauritius cane grown at Pusa and analysed at the same time under the same conditions.

	A	D	E	Red Mauritius cane.
Sucrose	11·61	10·62	8·41	18·80
Reducing sugar	0·83	0·96	3·58	0·26
Ash	....	0·24	0·15	....
*Albuminoids	0·31	0·30	0·21	0·62
CO_2 as $NA_2\ CO_3$	0·14	0·65	0·00	0·00
Water	86·44	87·20	87·12	79·35
Undetermined	0·67	0·63	0·53	0·97
Total ..	100·00	100·00	100·00	100·00
Specific Gravity	1·0557	1·0524	1·0523	1·0880
* Containing total N.	0·05	0·048	0·034	0·099

The main constituent of the dry matter in date juice, as in the case of cane juice, is sugar. The amount of the nitrogenous constituents is smaller than in the cane juice examined, but 0·099% of nitrogen in cane juice is abnormally high. Duplicate determinations, however, were carried out. Geerligs[1] gives 0·036% of nitrogen as an average figure for cane juice and says that it varies from 0·018 to 0·062, so that there is not much difference between the nitrogen content of cane juice and date palm juice.

Mineral matter in juice.—Leather[2] found for cane juice that the mineral matter varied from 0·25 to 0·49. The ash of the date palm juice seems rather less in amount than this.

Pectin bodies.—These were determined by precipitating 50 c.c. of filtered juice with an equal volume of alcohol, filtering off on to a tared filter, and after washing with alcohol, drying to constant weight.

An analysis carried out in this way gave 0·26% of pectin. This precipitate of course would also include gum present in the juice.

[1] Cane sugar and the process of its manufacture in Java. H. C. Prinsen Geerligs, page 12

[2] Agricultural Ledger, 1896, No. 19, page 17.

Nitrogen in juice.—The following table gives an idea of the form in which the nitrogen occurs in date juice. The figures are expressed as grams nitrogen per 100 c. c. of juice :—

Juice.	Total N.	N. Pptd. by $Cu(OH)_2$	N as NH_3 and amide.	N as NH_3
A	0·050	0·017	0·008	0·002
D	0·051	0·017	0·008	....
E	0·035	....	....	....
F	0·052	0·017	0·010	0·002

The proportion of N precipitated by various reagents is noted below, the total nitrogen originally present being expressed as 100.

	Parts original Nitrogen.	Parts precipitated by basic lead acetate.	Precipitated by phosphotungstic acid.
Date palm juice	100	10·8	18
Juice of Red Mauritius cane ..	100	20·0	11·1

Lead was removed before precipitation with phosphotungstic acid and the liquid concentrated to half its bulk.

Methods of Analysis.

Specific Gravity.—This was determined by means of the Westphal balance at Pusa and by hydrometer in camp.

Sucrose.—The juice was first clarified with dry basic lead acetate and the excess of lead removed with sodium phosphate. Readings were then taken in a Schmidt-Haensch ordinary light polariscope before and after inversion. The number of grams sucrose per 100 c.c. was found by the formula :—

$$\frac{(a-b) \times 26{\cdot}048}{143 - \frac{t}{2}}$$

where a equals direct reading.
b ,, invert reading.
t ,, temperature of the readings in °C.

Invert sugar.—For this the method of Brown, Morris and Miller was followed at Pusa.[1] The Cu_2O was estimated, however, by solution in a sulphuric acid solution of ferric sulphate. An amount of iron is reduced corresponding to that of the Cu_2O. The amount of ferric reduction was determined by titration with potassium permanganate whose strength was known in terms of CuO. The percentage of invert sugar was then calculated from the tables in the paper quoted.

The method was checked by preparing a solution of invert sugar of known strength by inverting pure cane-sugar. The solution was then diluted to 10 times its bulk and then contained in 10 c.c. 0·0975 gm. invert sugar. The invert sugar was then estimated in the solution by the method outlined above. Triplicate determinations were made, using 10 c.c. of the dilute sugar solution.

$KMnO_4$ used	c.c.
(1)	23·45
(2)	23·55
(3)	23·50
Average	23·50
less blank determination	0·55
	22·95

1 c.c. $KMnO_4$ was equivalent to 0·01032 gm. CuO.
∴ 22·95 „ is „ .. 0·2368 „ „

By the tables :—

0·2368 gm. CuO equals	·0973 gm. invert sugar.
actually present	·0975.

The method has frequently been checked, with equally good results. In camp the reducing sugar was determined by direct titration of the juice after clarification, against the copper solution.

Total solids.—A platinum basin containing cleaned pieces of pumice was brought to a constant weight, 10 c.c. of the juice was then run in and dried to a constant weight.

Total nitrogen.—This was determined by the Kjeldahl method using 25 c.c. of the juice.

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[1] J. C. S. Trans. 1897, page 278, et seq.

Ammoniacal nitrogen.—This was determined by the Sachsse-Schloesing-Longi method by distillation of the juice with magnesia at a pressure of 10—15 mm. and at a temperature of 35—40°C.[1]

Amide and ammoniacal nitrogen.—For this the juice was heated in the water bath for 6 hours with dilute HCl to hydrolise the amides. The ammonia was estimated by distillation as in the case of the ammoniacal nitrogen estimation.

Albuminoid nitrogen.—This was estimated by Stutzer's method, that is, precipitation with copper hydrate and then estimating the nitrogen in the precipitate by the Kjeldahl method.

Factors influencing yield and composition of the Juice.

The data given in the tables on pages 322-23, have in the case of four trees been plotted in curves (Charts 1 to 4), showing at a glance the yield of juice as the season advances. A reference to the curves brings out the interesting fact that they are of a similar type for all the trees. For each tree the jiran, dokat and tekat yields have been represented by separate curves. In general the yield is smallest at the beginning of the season (*Cf.* curves, p. 7, Studies of maple sap, by Morse, Bull. No. 32, New Hamps. Coll.). It gradually increases to its maximum at about the third week in January and then falls away again fairly rapidly till the end of the season.

Effect of climatic conditions. (a) Humidity.—An attempt was made to see if changes in the amount of moisture in the air affected the yield of juice, but no useful results were obtained.

(b) Temperature.—It is agreed throughout the date sugar districts, that the colder the nights, the richer and the more plentiful is the juice.

Newlands[2] records that in the case of the maple tree the best yields of juice are obtained during cold clear nights following bright warm days.

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[1] Trans. Guinness Research Lab., Vol. 1, Pt. 1 (1903).

[2] Handbook for Sugar Planters, Newlands.

During our experiments careful observation was kept of the daily maximum and minimum temperatures. The records of temperature are unfortunately not complete owing to continual absences on tour from Kotechandpur.

The charts shew that the yields are greatest during the coldest months of the year. Sudden changes in temperature seem to have very marked effects on the yield of juice. Thus on January 7th the temperature was very low. The yield of juice immediately after that date rose rapidly, though it is to be noticed that the effect of a cold night is not always seen that same night in an increased yield of juice. This increase comes the following night as a rule.

Rise of temperature results in immediately reducing the quantity of juice. This is well seen in the curves. From January 10th to 15th the night temperature rose rapidly. A sudden fall in yield is shewn in all the curves. From January 15th to 17th the night temperatures rapidly decreased. Most of the yield curves shew a corresponding rise in accordance with this. Towards the end of the season the yields of juice are too small to shew any marked variation corresponding to changes in temperature.

The writer suggests that during cold weather little growth of new leaves or flowers takes place in the tree and hence the colder the weather the more sap there is available to flow to the cut surface. Directly the temperature rises, growth goes on more rapidly and the supply of sap is diverted from the cut surface to the growing points.

With regard to the amount of sugar in the juice the curves give us interesting information. In all of them is to be seen a distinct connection between the yield of juice and its sugar content. As a general rule the smallest yields are the richest in sugar. Fischer[1] reports that when bleeding is active, the sap becomes gradually poorer and poorer in sugar.

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[1] Pfeiffer's Physiology of Plants, Ewart, Vol. 1.

Since writing this the author finds that a similar phenomenon has been noticed in the case of the maple tree in America (see Studies of Maple sap by Morse, Bull. No. 32, September 1895, New Hampshire College, Agric. Expt. Statn., page 4).

When, following a cold night a large yield of juice is obtained, there is an accompanying decrease in sugar concentration. As a consequence of this we see from the charts that whereas the curve for yield throughout the season is concave with regard to the base line of the chart, the curve for sugar content of the juice is convex. In other words, at the beginning and end of the season we have the lowest yields of juice, but at these times it is most concentrated.

In the middle of the season with the highest yields of juice we have the lowest concentrations of sugar.

The 'tekat' curves of trees Nos. 3 and 20 and the dokat curves of No. 11 are particularly good illustrations of this connection between yield of juice and its sugar concentration. Further it is to be noted that tekat juice is richer than jiran or dokat in sugar, but that its yield is much smaller.

(*c*) Cloudy, rainy or misty weather.—These weather conditions always affect the yield adversely. This is probably due to the fact that in these kinds of weather the night temperature is relatively high, but of course the high humidity might also have an effect in stopping bleeding. From the 12th to the 15th of January and the 31st of January to 8th February the weather was cloudy. From the charts it is seen that these dates correspond to rises in the night temperature.

Jiran versus *dokat and tekat juices.*—It is well recognised that dokat juice is much less in quantity than the corresponding jiran. The yield from tekat juice is much less still. The curves shew up these points very well. Towards the end of the season, however, the yield of dokat juice is frequently seen to surpass the jiran yields. (See charts for trees Nos. 3, 11 and 20.) This is explained by the fact that it is a common practice towards the end of the season to cut the tree both for jiran and dokat. Dokat juice obtained from a freshly cut surface is called *dokat-pocha.*

With regard to the amount of sugar in the juice dokat is supposed to be worse than jiran and tekat, much worse than either of these. Here it is perhaps in place to observe that a high yielding tree need not necessarily give a juice poor in sugar. High yield of juice, rich in

sugar, is frequently met with, and the trees at Khartalar, Jessore, are good illustrations of this. The trees were very heavy yielders, but the specific gravity shows the juice to be very concentrated.

The curves shew that very generally the sugar concentration is much lower in dokat than in jiran juice. The dokat curves for sugar concentration are seen in places to reach above the jiran curves, but wherever this is the case it corresponds to a low yield of juice, and, as we have seen, the amount of sugar in the juice of a particular tree depends largely on the amount of the juice-flow.

The tekat curves on the other hand shew that tekat juice is much more concentrated than either jiran or dokat. This is no doubt due to the small yield of juice. At the same time reference to the tables at pp. 322-23 for trees Nos. 3, 11, 16, and 20 shews that though tekat juice is rich in sugar a large proportion of this consists of reducing sugar. This is only natural, as after the juice has flowed from the cut surface for three days this surface has become very dirty and much yeast has grown on it. So that we should expect much fermentation to go on in the tekat juice.

Similarly for the same reason the proportion of reducing sugar in dokat juice is much higher than in jiran juice. One can see this on pp. 322-23 where the tables for trees Nos. 3, 11, 16 and 20 are given.

In our experiments the following are the extremes between which the amounts of sucrose and invert sugar have varied in jiran, dokat and tekat juice :—

	Sucrose.	Invert sugar.
Jiran	15·31 — 6·19	trace — 3·80
Dokat	14·01 — 4·37	trace — 3·80
Tekat	11·08 — 4·95	0·74 — 4·60

Cultivation.—The best cultivated gardens have generally been observed to give the best yields. The excellent garden at Khartalar (p. 325) is a very well cultivated one. Cultivation encourages a larger and more healthy growth of the tree.

[1] See Table on pages 325-26.

PLATE V.

Male tree.—The male inflorescence occurs as large loose bunches. The tree above has several such bunches and one is particularly well seen in the photograph.

Thickness of tree.—Careful note has been kept throughout the work of the relation of the yield to the thickness of the stem. It has always been found that thick stemmed plants give the highest yields.

Amount of foliage.—No definite relation has been established between this factor and the yield and composition of juice. Indications have been observed which tend to shew that trees with plentiful foliage give high yields. This fact is well recognised in the case of the sugar maple. Excessive stripping of the leaves for fuel and fodder should be discouraged as it is in the leaves that the sugar has its origin.

Healthiness of tree.—Trees have frequently been met with whose trunks have almost entirely rotted away near the base leaving simply a thin arch to support the trees. Strange to say these trees seem to give a very satisfactory yield.

Effect of soil.—The natives say that in sandy soils the yield and quality of juice are poorer than on heavier soils. This could not be determined by the author as it would require a separate enquiry of its own. All that can be said is that certain indications have been obtained which support the native saying. In this connection the reader is referred to the statement on p. 325 relating to the yields of juice at Khartalar. It will be seen that on this clay loam heavy yields were obtained of a uniformly rich juice.

Effect of flowering.—It has been stated that during flowering the quality of the juice falls off. N. N. Banerjee[1] states that the male trees yield sap early in the season and that the female tree yields its sap later on. These phenomena have not been noticed by us, although careful attention was paid to these points.

Individuality of the tree.—It has been continually observed by us that high yielding capacity of juice is a fairly constant character. This can be well seen by reference to the tables on pp. 308 to 323. A tree which is normally a low yielder such as No. 4 gives low yields

[1] Bengal Agri. Dept.'s Quarterly Journal, 1907, page 164.

throughout the season. Trees Nos. 2, 8, 10, 15, 17 and 19 are also obviously constantly low yielders. On the other hand, trees Nos. 5, 7, 9, 11, 16 and 20 give relatively constantly high yields.

Age of tree.—It is difficult from our figures to trace any direct connection between the age of the tree and the yield or composition of juice. Indeed, several years' work would be necessary in order to decide the question. It is generally stated that trees do not give their full yield until they are about 7 or 8 years old. Thus Robinson writes that if the trees are cut for the first time in their 6th year of growth then the yield of juice per tree is about $\frac{1}{2}$ the yield of juice of a tree of full maturity.

In the 7th year of growth the yield is about $\frac{3}{4}$ths and in the 8th year of growth the full yield is obtained.

In our experiments tree No. 16 which was only in its first year of cutting gave a fairly high yield. Trees which have been tapped for 36 successive years are still giving a good flow of juice.

Amount of inversion going on in the juice during the night.

The collecting pots are attached to the trees at any time after P.M., according to the nature of the weather. They are collected at any time after 6 next morning but many are not collected till 7 or 8 o'clock. So that much of the juice is exposed to the air 12—15 hours. In this time a certain amount of inversion might be expected to go on. To get an idea of how great the loss from this source might be the following experiments were made in February 1911.

A large quantity of juice was collected in the evening and several pots were about half filled with it and then hung up on trees again, trees of course which were not giving juice. The juice in each pot was analysed over night and again next morning. The results are shewn :—

PLATE VI.

Female tree.—The female inflorescence is slender and close. Careful observation of the photograph shews the tree to be in full flower. The inflorescences appear berry-like among the leaf stalks in the photograph.

Expt. No.	Date.	Time of collection.	Sucrose gms. per 100 c.c.	Reducing sugar gms. per 100 c.c.	% sucrose inverted.	Minimum night temperature °F.
1	15th February 1911 ..	6-30 p.m.	13·90	0·64	....	53
	16th ,, ,, ..	5-20 a.m.	11·75	1·04	15·47	....
	16th ,, ,, ..	7-30 ,,	9·20	1·80	33·67	....
2	15th ,, ,, ..	6-30 p.m.	11·63	1·28	....	....
	16th ,, ,, ..	5-20 a.m.	8·70	1·73	25·20	53
	16th ,, ,, ..	7-30 ,,	6·12	2·30	47·4	....
3(1)	17th ,, ,, ..	7 p.m.	11·65	1·25	....	55
	18th ,, ,, ..	7-45 a.m.	6·60	4·86	43·4	....
4(1)	17th ,, ,, ..	7 p.m.	13·30	2·20	....	....
	18th ,, ,, ..	7 45 a.m.	7·10	6·92	46·6	55
5(1)	17th ,, ,, ..	7 p.m.	13·40	1·19	....	....
	18th ,, ,, ..	7-45 a.m.	7·02	4·40	47·6	55
6	17th ,, ,, ..	7-45 p.m.	13·95	0·65	....	....
	18th ,, ,, ..	7 a.m.	12·25	2·87	12·2	55
7	17th ,, ,, ..	7-40 p.m.	13·90	0·34	....	....
	18th ,, ,, ..	7 a.m.	12·96	1.28	6·7	55
8	18th ,, ,, ..	8-10 p.m.	12·65	1·10	....	....
	19th ,, ,, ..	7 a.m.	6·00	5·40	52.6	56
9	18th ,, ,, ..	8-10 p.m.	10·55	0·70	....	....
	19th ,, ,, ..	7 a.m.	9·00	2·87	14·7	56
10	26th ,, ,, ..	7-30 p.m.	15.44	0.57	....	....
	27th ,, ,, ..	8 a.m.	14·77	1·47	4·34	....
	27th ,, ,, ..	8 a.m.	14·18	1·94	8·16	....
11	27th ,, ,, ..	9 p.m.	13·22	0·75	....	....
	28th ,, ,, .	7-30 a.m.	10·72	2·87	18·91	....
	28th ,, ,, ..	7-30 a.m.	10-80	3·24	18·31	....
12	28th ,, ,, ..	8-30 p.m.	11.75	0·97	....	....
	1st March 1911 ..	8 a.m.	7·48	4·04	36·4	....
	1st ,, ,, ..	8 a.m.	7·02	4·40	40·2	....
13	19th February 1911 ..	5-20 a.m.	10·80	0·53	....	56
	19th ,, ,, ..	7 a.m.	10·74	0·57	0·56	....
14	19th ,, ,, ..	5-20 a.m.	8·80	0·73	....	....
	19th ,, ,, ..	7 a.m.	8·70	0·81	1·1	56
15	16th ,, ,, ..	5-20 a.m.	10·65	1·47	....	53
	16th ,, ,, ..	7 a.m.	10·36	1·80	2·7	....

1 Mouths of pots covered tightly with cloths and hence juice warm (18° C.) This probably explains high amount of inversion.

A glance at the figures shews that the amount of inversion going on is large, varying from 0·6 to 53 per cent. Experiments 10, 11 and 12 were duplicated, and it is seen that the duplicates agree very well indeed. A few results are given shewing the amount of inversion going on after 5-30 A.M., as it appeared to the writer that much loss by inversion might be saved if the pots were collected by that hour; the present practice being to collect the juice much later. Experiments Nos. 1 and 2 shew the loss by inversion between 5-30 A.M. and 7 A.M., to be considerable, namely, 18·2 per cent. and 22·2 per cent., respectively.

On the other hand, experiments 13, 14 and 15 shew the loss during this period to be almost inappreciable. The difference in these results is explained by the fact that the juice used in experiments 1 and 2 was juice which had been standing in the pot overnight. It was, therefore, in full process of inversion and probably fairly warm. In experiments Nos. 13, 14 and 15 the juice used for the experiment was collecting in the pot from 8-30 P.M. to 5-20 A.M. and, therefore, it was not probably in full process of inversion and also it was probably much colder.

This fact also applies to all these experiments on inversion. The figures given shew the maximum inversion which can take place. In practice, the juice is running all night, and of course the later runnings are not exposed in the pot for anything like the length of time that the juice was which was used in these experiments.

Effect of Preservatives on the Juice.

A camp laboratory does not afford an opportunity for a very complete examination of date juice. Accordingly some 12 litres of good juice were collected and treated with various preservatives in order to keep them until arrival at Pusa. The following table shews the preservative used, the volume of juice and the direct reading of the solution in a Schmidt-Hænsch polariscope from time to time.

No. of Experiment.	Preservative.	Vol. of juice c.c.	Date.	Direct reading.	REMARKS.
				about	
I	Ether 80 c.c.	2,000	10th Feb. 1912	40·0	Jiran juice.
			11th „ „	27·4	....
			12th „ „	18·0	....
			Liquid still clear, but gaseous and smelt of alcohol.		
II	Formalin 3 c.c. of 40 %.	700	8th Feb. 1912	47·9	Jiran.
			11th „ „	47·9	(Filtered juice).
			12th „ „	47·9	Bottle almost completely filled.
			13th „ „	47·9	....
			17th „ „	46·7	....
			20th „ „	45·5	Free from alcohol.
III	Formalin 15 c.c.	2,500	11th „ „	40·3	Jiran (strained through cloth).
			20th „ „	21·4	Free from alcohol.
IV	„ 10 „	1,650	12th „ „	48·75	Jiran (filtered).
			20th „ „	44·00	....
V	„ 10 „	1,600	13th „ „	46·0	Dokat.
			17th „ „	42·3	(Strained through cloth).
			20th „ „	40·3	Free from alcohol.
VI	„ 15 „	2,500	12th „ „	44·9	Jiran.
			17th „ „	30·7	....
			20th „ „	25·5	No alcohol.
VII	Dry basic lead acetate 4 gms.	2,000	10th „ „	38·3	Jiran.
			11th „ „	35·6	....
			12th „ „	32·2	Gaseous and some alcohol.
			Not enough lead acetate added		
VIII	Dry basic lead acetate 8 gms.	1,800	11th Feb. 1912	39·0	Jiran.
			12th „ „	39·0	....
			20th „ „	34·1	....
			No alcohol produced.		
IX	Mercuric chloride 5 gms.	2,000	10th Feb. 1912	38·7	Jiran.
			11th „ „	38·7	....
			12th „ „	38·7	....
			20th „ „	38·4	....
			22nd „ „	37·8	....
			No alcohol produced.		
X	Do. 5 gms.	2,200	12th Feb. 1912	49·9	Jiran.
			20th „ „	42·1	....

As seen above, the juices were mainly collected on the 10th, 11th and 12th February and Pusa was reached on the 16th. Work on the juices was started at once so that most of them were in a fit state for further examination. Nos. I and VII were discarded altogether and No. III only used for the preparation of ash for analysis.

Formalin.—This seems to be very satisfactory. It was noted that formalin had more marked effects when the juice was first filtered through filter paper, than when it was simply strained through cloth. Thus in No. II the juice kept in a remarkable manner with no sign of change for 12 days and only 3 c.c. of 40 per cent. formalin were added to 700 c.c. of juice. It might be remarked here that formalin was observed to bleach the faint brownish colouration which a quite fresh date juice has. The other four experiments with formalin did not give as great an effect but the formalin seems to have checked the alcoholic fermentation only allowing the inversion of the sucrose.

Dry basic lead acetate in experiment No. VIII seems to have kept juice fairly well for some days ; but we should have doubtless obtained much better results had we filtered off the lead precipitate. It was unfortunate that the juice could not be examined for some days after the 12th owing to travelling. Dry basic lead acetate has been previously recommended for use in storing juices. In a series of experiments described by Spencer[1] a sample of cane juice preserved with this reagent gave the following percentages of sucrose after successive intervals of 24 hours except where otherwise stated: 16·98, 16·96, 16·98, 16·96, 16·98, 16·98 (interval 48 hours), 16·98 (interval 48 hours), 16·96; after a further interval of 5 days there were indications of fermentation.

Our experiments are not so favourable to the use of dry basic lead acetate, but it is possible we did not use a sufficiency of the reagent. It might be of interest here to mention that on several occasions in camp juices which had been clarified with basic lead acetate and analysed one day were found unchanged on analysis the following day. Thus one may take samples of juice in the field and add dry basic lead acetate on the spot and there need be no fear of their undergoing change if one is delayed by an hour or two in carrying out the analysis.

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[1] Handbook for Sugar Manufacturers, p. 85.

Mercuric chloride.—The experiments shew this to be a very effective preservative. By an oversight however much larger amounts of the substance were used than are really required.

Acids present in Date Juice.

About 6 litres of preserved juice free from fermentation were distilled in steam after acidifying with 0·5 per cent. of sulphuric acid. About 4 litres of distillate were collected. The distillate was practically neutral and was not further examined. The residual liquid in the flask was extracted with ether in a large separating funnel. About 15 c.c. of the liquid was shaken with about 200 c.c. of ether at each extraction until all the liquid had been so treated. The whole process of extraction was gone through in a similar way with a fresh lot of ether. The ether extracts were then combined and the ether distilled off. About one half of a c.c. of a tarry liquid of a very bitter taste was left behind together with 7 or 8 small clusters of crystals. Attempts to purify the crystals failed as they were present in such small quantity—only a few milligrams at the most. They were readily soluble in water and alcohol, and had an acid reaction and a cooling sharp taste. On examination under a microscope fitted with a polarising apparatus the crystals were seen to be needle-shaped and gave interference bands on rotating the Nicols, the play of colours being very brilliant. Crystals of malic acid appeared to be of the same crystalline form and behaved in a similar manner under polarised light. Only one form of crystal was observed. On solution in water and addition of neutral lead acetate a curdy precipitate was obtained.

Attempts to recover the free acid by decomposition of the lead salt with hydrogen sulphide failed.

Cause of alkalinity of the juice.

It has already been stated that date palm juices when first drawn from the tree are alkaline to litmus paper.[1] The quite fresh

[1] The sap of the Buri palm (Corypha elata) has been shewn to be alkaline when freshly drawn. (See Gibbs "The Alcohol Industry," Part I, Philippine Jour. of Science, June 1911, Series A, p. 176.)

unfermented juices are quite strongly alkaline to litmus and to methyl-orange. A juice tested at Pusa which was still alkaline to litmus and methyl-orange was found to be acid to phenolphtalein, but this was the only juice which we had an opportunity of examining with phenolphtalein.

Fresh juices always give a small amount of effervescence on adding acid to them.

Some juices were titrated with sulphuric acid using litmus as indicator.

The following amounts of alkalinity reckoned as gms. Na_2CO_3 per 100 c.c. of juice were obtained.

Tree in compound	0·092
,, No. 20	0·025
,, ,, 3	0·05
Average sample for daily boiling..	0·012

It seemed probable that the alkalinity of the juices was due to alkaline carbonates.

At Pusa some determinations of free and combined CO_2 in two date juices which were still alkaline were carried out gravimetrically, 50 c.c. of the juice was first boiled and CO_2 evolved collected in weighed soda lime tubes. Dilute hydrochloric acid was then added and any liberated CO_2 was collected in weighed soda lime tubes, the liquid being boiled towards the end of the process.

The figures below show the amount of (*a*) free and (*b*) combined CO_2 present in the juices expressed as grams Na_2CO_3 per 100 grams of juice.

	Gms. per 100 gms.	
	Free CO_2 calculated as Na_2CO_3	Combined CO_2 calculated as Na_2CO_3
Juice A	0·0019	0·14
,, D	0·052	0·047

These amounts are quite sufficient to account for the marked alkalinity of the juice. At the same time it must be remembered

that if basic nitrogenous compounds are present they also would have an alkaline reaction.

Juice A was known to be practically free from fermentation and the small amount of free CO_2 proves this. It corresponds to juice II (see page 341 of this memoir). CO_2 determinations were carried out on 18th February 1912, when the direct reading shewed but little change.

Juice D corresponds to juice V on that page, and it is seen that more change has gone on than in the case of juice A, and hence the amount of carbonate would be expected to be less. The amount of free CO_2 present points to fermentation.

The Sugars of the Palm.

An enquiry into the kinds of sugars in the wild date palm does not appear to have been made. It has been assumed that they are the same as those occurring in the cane. It appeared desirable to make a thorough examination of the sugars present in order to see whether or no this is the case.

In the first place, experiments in the field shew that cane sugar is the only sugar normally present in the sap as it runs from the tree. By keeping the surface of a tree specially clean only the merest trace of reducing sugar has been found in the juice certainly less than 0·01 per cent.

About 100 gms. of mixed Gnour and Akrah sugars were dissolved in hot 80 per cent. alcohol and filtered. The filtered solution was agitated for about an hour and then allowed to stand. After 2 days numbers of fine crystals had formed, apparently cane sugar. The crystals were dissolved in as small as possible a quantity of distilled water and an excess of absolute alcohol added and again thoroughly shaken for an hour. In a couple of days crystals had again formed.

Some cane sugar, Cossipore 2nd white, was once recrystallised by the same method. Both sugars were dried at 100°C and examined as follows :—

Rotatory power.—6·512 gms. were dissolved in water and made up to 50 c.c. The solution was then read in a Schmidt and Hænsch Saccharimeter. The following readings were obtained :—

		=Sucrose.
Sugar from date palm	49·9	99·80
Cane sugar	49·7	99·60
Theory for pure cane sugar	50·0	100·00

The solutions were then inverted by adding 1/10 of their volume of hydrochloric acid and heating to 68° C. in 15 minutes.

The invert readings uncorrected for dilution were :—

Sugar from date palm	12·6 (t = 30° C.)
Cane sugar	12·6 (t = 30° C.)

Melting point.—The melting points of the above two sugars and of some Tate's cube sugar were determined under exactly similar conditions. The following results corrected, were obtained :—

Sugar from date palm	181° C.
Cane sugar (as above)	182° C.
Tate's cube sugar	182° C.

It may be mentioned that the melting point of sucrose is given in all text-books as 160—161° C. Beilstein also gives 160, but mentions that 180 was found by Péligot. Under no circumstances were we able to get sucrose to melt at 160—161°, and this statement of the melting point of sucrose in text-books needs correction.

The sugar separated from the date palm is therefore shewn to be sucrose as in the case of cane sugar.

Fifty gms. of date gur were dissolved in water. A determination of the amount of reducing sugar present was made, and this amounted to about 7 per cent.

To the above a solution of phenyl hydrazin acetate was added containing 12 gms. phenyl hydrazin, 12 gms. of glacial acetic acid and 30 c.c. of water. The liquid was heated inside a water bath for $2\frac{1}{2}$ hours. An osazone began to separate after 25—30 minutes. The crystals were filtered off at the pump and washed with water and then alcohol and dried. The weight of the crude osazone was about 10 gms.

About 5 gms. of the osazone were completely dissolved in as small a quantity of boiling alcohol as possible, filtered through a hot funnel and allowed to crystallise. The crystals were washed with water and alcohol at the pump and dried.

The mother liquor was evaporated down, filtered through a hot funnel, allowed to cool and crystallise. The crystals were then washed with water and alcohol as before. By repeating this process four crops of crystals were obtained in all. Each crop was then examined :—(*a*) for its melting point, (*b*) microscopically.

(*a*) *Melting point corrected.*—For this determination it is essential that the process of heating be carried out very rapidly and exactly in the same manner in each test. In these tests the temperature was raised from 190 to the melting point in $2\frac{1}{2}$—3 minutes :—

Crop I	206	Crop III	206
„ II	206	„ IV	205·5

(*b*) *Microscopic Examination.*—This revealed in all cases a mass of needle-shaped crystals arranged in the characteristic bundles into which glucosazone collects. Only one form of crystal could be observed.

Glucosazone was now prepared by inverting some pure cane sugar and forming the osazone as above. On recrystallisation from alcohol its melting point was found to be 206 (corrected). Its microscopical appearance was exactly like that of the osazone obtained above.

Some of the osazone from date gur was next finely ground with the pure glucosazone. The melting point of the mixture corrected was 206.

The above experiment on the formation of osazones from date gur was repeated and also carried out with raw date sugars and with some of the juices which had been treated with preservative and brought to Pusa. The osazone obtained always had the same properties.

Hence the only osazone formed is glucosazone.

Glucosazone is formed by glucose, levulose or mannose. Hence the only sugars which can be present in the date juice are cane sugar, glucose, levulose and perhaps mannose.

Mannose was tested for in the following[1] way :—

10 gms. of Akrah sugar were dissolved in 25 c.c. of water, clarified with a pinch of anhydrous basic lead acetate and filtered. The lead was separated by means of sodium phosphate and the solution again filtered. One per cent. of its volume of glacial acetic acid was now added and the volume made up to 75 c.c. ; 5 c.c. of phenyl hydrazin, 5 c.c. of glacial acetic acid, and 12 c.c. of water were now added. The mixture was then well agitated for half an hour and left for 24 hours. Three tests were carried out but in none was the hydrazone of mannose formed.

We must conclude then that the sugars normally present in the juice of the date palm are the same as those which occur in the sugar-cane.

Composition of Date Juice Ash.

About one gram of ash was prepared by concentrating the juice and igniting the residue. A pure white ash was thus obtained. It had the following composition :—

	Per cent.
K_2O	55·08
Na_2O	7·85
CaO	0·48
MgO	2·51
Co_2	13·30
Cl_2	12·89
So_3	4·64
P_2O_5	1·57
Insol. silica	0·82
Soluble silica	0·86

It is to be noted that the ash is very rich in potash and that it also contains a rather high proportion of chlorine.

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[1] Bull. de l'Assoc, des Chim. de Sucr, et de dist., 1901, 18 (10), 758-69.

PLATE VII.

Boiling down the juice.—On the right is the rack on which the boiling pans are placed from day to day, the fuel—rahar stalks and palm leaves—is seen piled in background.

PART VIII.

MANUFACTURE.

BOILING.

THE boiling apparatus called the *bain* is prepared in the shade of a tree and commonly surrounded by a fence of date palm leaves. It generally consists of a hole of about 3 ft. in diameter sunk about 2 ft. in the ground over which are supported by mud arches,[1] four thin earthen pans of a semi-globular shape (see plate VII) and 18″ in diameter. One *bain* may contain however as many as 16 pans or as few as 2. The hole itself is the furnace and has two apertures on opposite sides for feeding in the fuel and for the escape of the smoke. The juice is poured into the pans and the fire is lit and the boiling continued for 3—4 hours until the liquid is of the right density. Small amounts of scum are removed from time to time, but the amount of this is much less than in cane juice, being almost negligible. Dried date leaves are laid over the surface of the pan to allay the frothing. The bubbles which appear in the pans mark the different stages of boiling, they being styled as spider (*makarsha*) bubbles, mustard flower (*sarsafuli*) bubbles, tiger (*baghai*) bubbles and treacle (*guria*) bubbles, which last indicate that the process is nearly complete. The liquid is finally of a lovely golden colour and is ladled out into earthen pots or jars varying from 5—20 seers in content and allowed to cool to form gur. Before being poured into these pots, however, a handful of gur, called the *bichh* is added to the contents of each pan and the whole well stirred. The crystals added promote crystallisation in the liquid. This *bichh* is prepared daily and great attention

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1 The size of the furnace and number of pans depend on the size of the garden of course. The writer has seen as many as 13 pans on one furnace.

is paid to its preparation. The process of preparing *bichh* is called *bichhmara* and is as follows. A small portion of the liquid as its boiling approaches completion is set apart in one of the pans and boiled down rather more rapidly than the liquid in the other pans. Great care is, however, paid to its boiling. When the liquid has reached a certain consistency the pan is removed from the fire. The attendant takes a stick and with it rubs a portion of the liquid vigorously up and down in the form of a streak on the inside of the pan. The streak of liquid gets more and more sticky and finally white crystals of sugar may be seen. The operator tells from the ease with which these crystals come whether the day's boiling will be good or not. If the liquid is too thin and crystals cannot readily be obtained the pan is returned to the fire and heating continued until the liquid is of the right consistency. It is then vigorously stirred after removal from the flame when it becomes a pasty mass. Any excess of this beyond the amount required for *bichh* is poured out into a flat basket whose surface has been wetted with water to prevent the sugary mass from sticking. A flat mass of sugar which sets to a hard cake is thus obtained. This flat cake is known as *Patali* and is commonly on sale as a sweetmeat in the date districts at about Rs. 2-8-0 to 3-0-0 per katcha maund.

The residue in the pans is soft and contains crystals which serve as nuclei for crystallisation when added as *bichh* to the main bulk of the boiled juice.

The fuel mostly employed for the boiling process is Sundri wood (*Heritiera littoralis*), which forms the principal part of the wild tree vegetation of the Sunderbans. The under leaves stripped from the date trees are also used as fuel as well as the wood of old date trees which have been cut down. Stalks of rahar (*Cajanus indicus*), which is often grown as an undercrop in date gardens are also commonly in use as a fuel. In a few places near railway lines coal has been used.

The outturn of gur is from $\frac{1}{7}$ to $\frac{1}{9}$ the weight of the juice.

For a description of the native methods of refining the gur and of the methods of making the various kinds of native date sugars see page 359.

Yield of Gur per Tree.

On page 325 it is shown that 170lbs. of juice per tree per season may be taken as a fair average yield. So that the average annual yield of gur per tree is 170/8 or 21·25lbs.

Enquiries among intelligent cultivators seem to shew this figure to be reliable. Three instances of these enquiries are given. From 120 trees one man produced 26 maunds of gur (pacca). This is equivalent to just over 17lbs. of gur per tree. To this must be added the amount consumed by him. A second man working with 80 trees reckoned he had produced from them 20 maunds (pacca) of gur. This is equal to 20lbs. gur per tree. A third man produced Rs. 135 worth of gur from 180 trees. Included in this was gur, etc., to the value of Rs. 35 consumed by his family. Rs. 135 is the equivalent of about 4,320lbs. of gur. Therefore the yield of gur per tree works out at 24lbs.

Yield of Gur per Acre.

Three hundred and fifty trees could conveniently be grown per acre, so that the yield per acre would be $350 \times 21\frac{1}{4}$lbs. equal to 3·3 tons. Actually only 240 trees are usually grown per acre, and this therefore equals 2·3 tons of gur which is still a much higher yield than is obtained from cane in Jessore.

It will now be of interest to quote the writings of various other authors on the yield of juice and gur from date trees.

Robinson[1] in some calculations of yields from date trees takes the first day's yield per tree as 10 seers, that of 2nd day's as 4 seers, and that of 3rd day's as 2 seers. This averages out at $5\frac{1}{3}$ seers of juice per collecting day. Robinson moreover states[2] that his figures are under rather than overestimated. From the preceding figures

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[1] Bengal Sugar Planter, page 51.

[2] Loc. cit.

he calculates[1] that the annual produce of a full-grown date plantation was $78\frac{3}{4}$ bazar maunds[2] of gur per Bengal beegah,[3] or nearly $19\frac{3}{4}$ seers or $39\frac{1}{2}$℔s. from each tree.

To arrive at this result he assumes that there are 160 trees per beegah, and that 69 of these trees are cut daily.

Sixty-nine trees yield bazar maunds 9, seers 8, daily of juice using his figures.

He takes the average productive season at 107 days. Thus the number of productive days per tree in a season is equal to $\frac{69}{160} \times 107 = 46$. In this period, however, are included days in which the yield is diminished by rain or by fogs. To allow for this he deducts $\frac{1}{5}$ of the total yield. We then get daily 160×9 maunds 8 seers of juice which is equal to bazar maunds 787-20-13, as the produce in juice per season per beegah deducting $\frac{1}{5}$ for bad weather as above. The average produce per tree therefore comes out at maunds 4-36-4 or 392℔s.

A correspondent of the Calcutta Agricultural Society in a letter published in the 5th volume of the Society's Transactions and dated Jessore, July 1846,[4] gives the average yield from a healthy date tree for the season at 30 seers gur and from an indifferent tree at 10 seers of gur. He thence assumes an average of 15 seers of gur which is equivalent to 3 maunds, 30 seers of juice.

Drury[5] puts the average yield per tree of juice at 180 pints per year which is equivalent to 22 gallons or about 2 maunds 30 seers.

Referring to more recent figures Mr. Kirtane[6] in experiments made by him in the Rampura Parganna of the Indore State in 1901-02, found the average yield per day to be $4\frac{1}{2}$℔s. of juice per tree and the maximum daily yield of one tree 14℔s. The juice must have been richer than that of Jessore since 6℔s. of juice yielded one of gur.

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[1] Bengal Sugar Planter, page 55.
[2] One bazar maund equals 80lbs.
[3] Roughly $\frac{1}{3}$ acre.
[4] Bengal Sugar Planter, page 55.
[5] The Useful Plants of India, by Col. Heber Drury, London, 1873.
[6] Files of the Reporter on Economic Products.

In a note on the Administration of Bengal 1901-02 (published 1903), page 2, it is stated that a tree yields on an average 5 seers of juice every day and about 15 seers of gur per season. This is approximately the same figure arrived at by Robinson.

N. N. Banerjee[1] also quotes 5 seers per day as the average yield of juice per tree. He assumes the number of sap yielding days as 50 and hence arrives at the average annual yield of 250 seers per tree.

N. G. Mukerji[2] quotes this same figure.

U. N. Kanjilal[3] in a very good account of the industry puts the average yield of juice per tree at 10 seers a day. This is of course quite an impossible amount.

Westland[4] also quotes 5 seers per night (exclusive of the quiescent nights) as a regular average from a good tree.

H. D. Chatterjee[5] as a result of experiments on wild date trees in Khandwa, C. P., puts the average yield of juice per night there (exclusive of quiescent nights) at 3 seers per tree.

It might here be mentioned that the maple tree which is tapped for sugar in North America in a somewhat similar way produces on an average 4lbs. of sugar in a season. Its juice contains only 3 per cent. of sugar.

Experiments on Losses of Sugar during Boiling.

The following table explains the lines of these experiments. Boiling of the juice commences according to the time of year any time from 7 A.M. up to 9 A.M. It is all collected in the earthen pots placed over the furnace described at p. 349. No clarification of any kind is attempted and there is very little scum, as is seen by the table. A date palm leaf is immersed in the boiling liquid to keep it from frothing over. The juice is colourless or faintly brownish when collected

[1] Quarterly Journal, Bengal, Vol. I, page 164.

[2] Handbook of Indian Agriculture, 2nd Edition, page 329.

[3] Indian Forester, December 1892, page 454.

[4] Report on the District of Jessore, Calcutta, 1874, page 164.

[5] Is it an experiment or a national industry ? Haridas Chatterji, Central India Press, Mhow, 1901, page 13.

and during the boiling gradually changes to a golden yellow. The boiling takes 3 to 4 hours and is stopped when the liquid reaches a certain stage of stickiness which is judged by dropping it from the end of a stick. The liquid is then placed in ordinary earthenware *ghurras* and stored away for 10 to 14 days to crystallise when it is taken to the towns and sold to the refiners or khandsaris. The boiling operation is described in greater detail at page 349 of this memoir.

Date.	Juice.				Gur.			Losses.		Remarks.
	Total weight.	Sucrose.	Reducing sugar.	Total sugar.	Per cent. gur from juice by weight.	Sucrose.	Reducing sugar.	Sucrose per cent.	Total sugar per cent.	
	lbs.	lbs.	lbs.	lbs.		lbs.	lbs.			
4-12-11	65·0	7·84	0·27	9·33	14·35	6·44	0·37	17·86	16·03	Garden I, two pans.
7-12-11	158·15	19·19	0·58	23·19	14·66	17·62	0·52	8·91	8·24	Garden I, four pans.
7-12-11	158·15	16·32	1·08	19·87	12·56	14·82	0·82	10·12	10·11	Garden II, four pans.
8-12-11	142·01	17·29	0·76	19·90	14·01	13·31	0·51	23·02	22·39	Garden I, four pans.
9-12-11	190·54	20·52	1·61	24·56	12·89	17·04	1·31	16·96	17·08	Do.
11-12-11	148·30	15·50	1·52	20·31	13·70	14·84	1·34	4·26	4·93	Garden II, four pans.
19-12-11	121·4	14·18	1·86	18·09	14·90	13·07	1·69	7·83	7·98	Chowgachha, two pans.
20-12-11	107·5	12·36	1·52	17·12	15·93	12·36	1·35	·00	1·22	Do.
22-12-11	208·9	23·14	1·43	28·84	13·81	20·75	1·59	10·33	9·07	Tarpur.
5-1-12	244·9	21·79	2·97	32·68	13·34	19·08	3·99	12·44	7·19	Jhenidah, four pans.
6-1-12	115·63	11·40	1·19	17·00	14·70	11·25	1·59	1·71	...	Kaliganj.
17-1-12	313·92	31·31	2·82	38·94	12·40	29·06	2·11	7·19	8·67	Garden I, four pans.
21-1-12	227·07	23·93	2·84	32·37	14·26	23·88	2·44	0·21	1·68	Maladharpur, four pans.
22-1-12	545·30	56·30	7·63	73·19	13·42	51·14	7·36	9·16	8·49	Maladharpur, eleven pans.
	Duplicate	56·57	7·63	...	...	50·18	7·56	11·30	10·06	
23-1-12	199·0	19·12	4·95	27·16	13·65	18·87	4·10	1·31	4·57	Maladharpur, four pans.
31-1-12	393·62	...	..	48·00	12·19	29·39 29·18	6·70 6·70	8·24	8·75	Garden I, four pans.
4-2-12	212·37	...	...	29·50	13·89	19·06	3·62	9·45	7·05	Jessore all jiran.
12-2-12	246·4	23·09	1·90	22·69	9·21	16·20	1·62	29·84	28·7	Mostly jiran juice.
13-2-12	251·9	22·87	5·26	20·31	8·06	12·54	2·60	45·17	46·2	Mostly dokat and partly tekat and jiran.
21-2-12	111·32	12·95	1·52	13·25	11·90	9·34	0·99	27·88	28·6	Mostly jiran.

The experiments carried out during February 1911 shewed that very great loss of sugar had taken place during the boiling, varying from 28 to 46% of the total sugar.

The work of season 1911-12 however shews the loss to be much smaller but very variable. Here the loss of sucrose varies from 0 to 23% and the loss of total sugar from 1·22 to 22·39.

For the 20 experiments the average loss of sucrose works out at 12·5% and of total sugar to 12·2%.

When it is remembered that the juice is normally alkaline the loss of sugar during boiling should not be very high. At times however the juice when ready to be boiled is acid owing to fermentation having set in. Thus in the experiments carried out in February 1911 when the losses of sugar were so high all the juices were strongly acid.

The earthen pans in which the boiling is performed are never cleaned out. New pans are bought at the beginning of the season and after each day's boiling the syrup is simply drained out and the pans put by till the next day.

The same pans are in use daily throughout the season. One may imagine the filthy state to which they attain. Burnt sugar collects in the pans and must contribute largely to the dark colour of the gur. The reason why the pans are not cleaned out is that the people think if water is put into them they will crack when again put over the fire.

In order to give an idea of the amount and composition of the scum formed during the boiling the following figures are quoted :—

Juice.			Scum.		
Total wt. lbs.	Total sucrose lbs.	Reducing sugar lbs.	Total wt. lbs.	Sucrose lbs.	Reducing sugar lbs.
115·2	10·51	2·02	0·75	0·02	0·06
164·7	15·01	2·57	1·06	0·09	0·04
110·8	11·01	1·47	0·94	0·007	0·108
103·7	....	....	1·44	0·09	0·08
147·6	14·92	2·17	1·75	0·12	0·11
97·9	9·26	1·39	0·94	0 09	0·025

The conclusion is that the amount of sugar lost in the scum is not large, being much less than 1%.

The figures in the two preceding tables give an idea of the amount of juice which is usually boiled by a cultivator in the district. In the experiments above recorded the number of trees tapped for a single boiling varied from 20 to 130. It has been suggested that the introduction of iron pans for boiling would be an improvement, but it is a question if they would be worth while for such small amounts of juice. Again the man who only boils the juice from 20 trees daily cannot afford to invest in, say Rs. 20 for an iron pan.

Here it will be worth while to insert a few figures shewing the losses of sugar in boiling cane juice.

Leather[1] found in experiments at Cawnpore and Poona that the total loss of sugar on boiling cane juice into gur by the country open pan method was 9·76—13·95%.

Clarke[2] as a result of 13 experiments in the United Provinces found an average loss of total sugar of 15·7% and of sucrose of 19·7%. Clarke[3] has since shewn that about 5% of this loss goes in the scum which is skimmed off during boiling.

The author of this paper found as a result of 25 experiments at Partabgarh, United Provinces, in 1909-10 an average loss of sucrose of 18·45% and of the total sugar 14·80%.

The three sets of experiments outlined above shew that the average loss of cane sugar during the native process of boiling the juice amounts to not more than 20% and of total sugar 15%. Five per cent. of this loss is accounted for in the scum removed.

The average loss of sugar in boiling date juice was shewn by the writer's experiments to be 12·5% of the total sugar and about the same quantity of sucrose.

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1 Agricultural Ledger, 1896, No. 19, page 15.

2 Sugarcane at the Partabgarh Experimental Station, 1908, Bull. No. 13 A. R. I., Pusa.

3 "The Efficiency of the Hadi Process of Sugar Manufacture," Agricultural Jour. of India, Vol. V, Part I, page 38.

The fact that the percentage loss of sucrose and total sugar is about the same would appear to indicate that the sugar is actually being burnt up in the case of date juice. In the case of the cane juice a good proportion of the sucrose which disappears has been inverted and not altogether destroyed.

It is probable that the total destruction of so much sugar is due to the use of earthenware pans.

Owing to the structure of the furnace much of the sugar is caramelised. The date gurs and mollasses are much darker than the corresponding products from the cane. This is almost certainly largely due to this caramelisation of the sugar. Further, boiling down the juice in earthenware pans requires a much longer time than the same process would in iron pans and hence there is more opportunity for caramelisation to go on. One can see the sudden change in colour which the date juice undergoes on being put into the pans. From a colourless juice it turns brownish at once.

Quantity of Sugar stored in the Date Palm.

A tree which had been tapped at varying intervals during the season was cut down. It was about 30 feet high and had been tapped for some 18 years. The tree was sawn into logs at roughly every 5 feet from the base. By this means 6 logs were obtained. Measurements of each log were taken and one of them weighed, but unfortunately a mistake was made in the weighment. However by assuming the weight per cubic foot as 45℔s. an average figure for woods, we can get a very near estimate of the weight of the whole tree. The saw-dust obtained while sawing the tree into logs was collected. The head of the tree, that is, the top log containing the tapped surface, was sawn longitudinally into two pieces in order to get a sample of the wood as saw-dust. We thus obtained 7 samples of the saw dust.

Each of the 7 samples of saw-dust was immediately analysed within ten minutes of being collected. The sucrose and reducing

sugar were determined in each sample. The table sets out the total sugar per cent. in the tree at various points. No. 1 sample was from the base of the tree and No. 7 was from the top portion—

No. of sample.	Total sugar. Per cent.
1	1·03
2	1·48
3	3·00
4	4·40
5	4·70
6	4·90
7	4·10

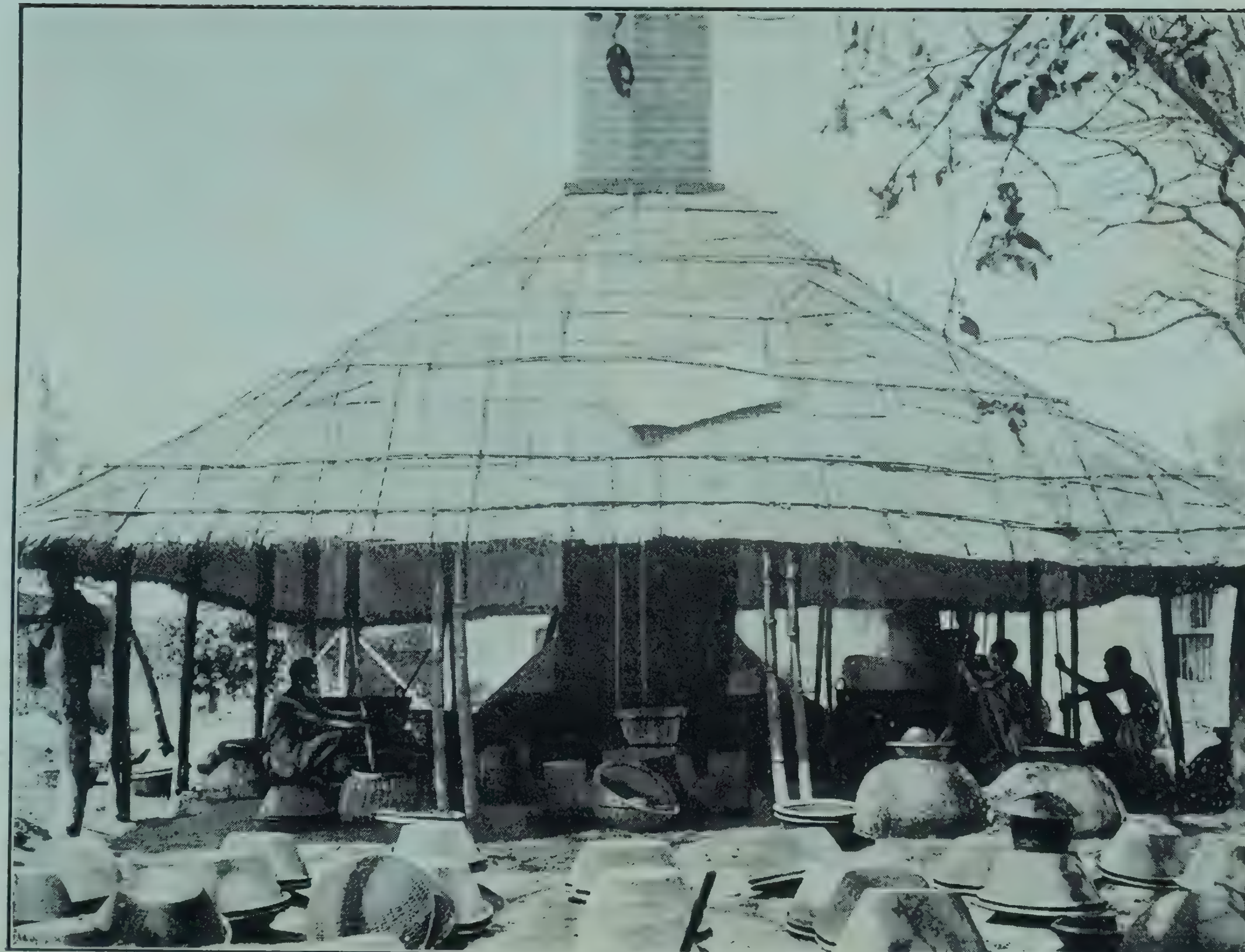
It is interesting to note that there was only the slightest indication of bleeding from the stump of the tree. At no portion of the tree was the cut surface notably damp, but the sawn surfaces became gradually damper as one proceeded upwards.

The total volume of the tree was 17·65 cub. feet. At 45lbs. per cubic foot the tree would, therefore, weigh 794·5lbs. The accompanying table sets out the weight of the various logs—with the weight of sugar in each.

Log.	Total weight.	Total sugar.
	lbs.	lbs.
Top log	65	2·67
Next lower log	108	5·18
Do.	135	6·21
Do.	153	5·80
Do.	157	2·75
Lowest log	175·5	2·20
	793·5	24·81

The tree therefore contains only about 25lbs. of sugar altogether. Further there is no special accumulation of sugar at the top of the tree. It has been shewn that an average tree yields about 22lbs. of gur per season. This tree had only been tapped a few times during the current season. Therefore it is reasonable to assume that the sugar is being formed from some other substance, probably starch, during the bleeding process.

PLATE VIII.



Native sugar refinery.—Boiling place. The molasses is here reboiled into a second crop of gur. The iron pans can just be made out. In the foreground may be seen the pots containing the molasses gur, which are buried to the neck in the ground. Their mouths are covered with earthen pans, but one in the right foreground is uncovered.

With regard to this point Brandis[1] says that preparatory to the production of flowers and seed the parenchyma in the trunk of Phœnyx is full of starch which at the time of flowering is transformed into sugar.

The Native Refining Process.

The khandsaris (refiners) having purchased the gur from the middlemen, break the pots and scrape out the contents. It is then broken up and placed in big baskets, each of $2\frac{1}{4}$ maunds capacity. The baskets, supported by bamboo triangles, are put over earthenware pans and left in the open and the molasses allowed to drain for 3—4 days. The baskets are next put inside a shed over similar pans and a layer 4—5 inches deep of moist *pata shyali* (Vallisneria spiralis), a water weed, is put on the surface of the sugar. Moisture drains down through the sugar, washing out the molasses. The weed has the property of taking up moisture from the atmosphere and thus keeps more or less damp for some time. It is also credited by the natives with the property of bleaching the sugar. After a week the *shyali* is removed and a layer of white sugar 3—4 inches deep has been formed. This is then cut off by knives, broken up and spread in the sun on grass mats to dry, being pressed with the feet of the coolies from time to time (see Plate I). When dry it is beaten up with wooden mallets to make it look whiter. The water weed is then replaced by fresh weed and after a week 3—4 inches more of sugar is removed. The contents of several baskets are then mixed to make up one basket and the process repeated until all is finished. At Kotechandpur sugar prepared in this way is called Akrah. At other places it is called Dulloah or Dollo. The baskets used in the process are boiled in water from time to time to prevent fermentation of the sugar which would otherwise take place.

The molasses collected by simple drainage is called *Agamata*. That collected under the water weed treatment is called *Farasu-*

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[1] Indian Trees, p. 643.

mata. These two kinds are mixed in equal proportions and boiled down to get second gur by the refiner himself. Each refiner has his own boiling pans in his factory yard. A photo of these boiling pans is shewn in Plate IX. They are also seen in the background in Plate VIII. They consist of generally 4 iron pans each of capacity $1\frac{3}{4}$ bazar maunds of juice. They are arranged regularly around a central chimney stack and each has a furnace under it. Coal is usually burnt. The whole is covered by a roof. When boiling is complete the thick liquid is transferred to a large earthenware pot.

A handful of raw sugar crystals is now stirred in to encourage crystallisation, the stirring being continued for some time. The liquid is now transferred to big earthenware pots of the shape shewn almost completely buried in the soil as illustrated in Plate VIII. An earthen pan is placed over the mouth and the pots left for about 3 weeks to crystallise. In Plate VIII these partly buried pots are seen in the foreground with their mouths covered over. The open mouth of one is seen to the right of the picture. Each pot holds about 3—4 maunds. Burying the pots in earth prevents the liquid being disturbed, any disturbance being detrimental to the formation of good crystals. Also cooling takes place more slowly and slow cooling encourages large crystal formation.

This second gur finally goes through the same processes of draining off molasses in the open and then by the use of water weed, as the gur does. The sugar however is not supposed to be of such good quality. It is called Gnour at Kotechandpur.

The final molasses is called *Chitu.* The following table shews one experiment on the determination of the loss of sugar taking place during the boiling of the first molasses. With the huge fire kept up much of the sugar is burnt and it is surprising the loss is not greater than is shewn in the table.

PLATE IX.

Dobarrah sugar manufacture.—The boiling pans. The large iron pans as well as the small brass ones are shewn. In the foreground is seen a pot of the boiled product being treated with water weed to refine it to white sugar.

Date.	Molasses.						Gur.						Losses.				
	Total weight.	Cane sugar.	Reducing sugar.	Sucrose.	Reducing sugar.	Total sugar.	Total weight.	Sucrose.	Reducing sugar.	Sucrose.	Reducing sugar.	Total sugar.	Sucrose.	Reducing sugar.	Sucrose.	Reducing sugar.	Total sugar.
	lbs.	per cent.	per cent.	lbs.	lbs.	lbs.	lbs.	per cent.	per cent.	lbs.	lbs.	lbs.	lbs.	lbs.	per cent.	per cent.	per cent.
3-3-11	123	64·68	15·7	79·56	19·31	98·87	105·5	70·63 70·63	8·83 8·83	74·51 74·51	9·32 9·32	83·83 83·83	5·05	9·99	6·35	51·74	15·21

A duplicate analysis was made of the gur and it is quoted. Analyses are also given of the 3 kinds of molasses, *viz.*, *Agamata*, *Farasumata* and *Chitu*.

No.	Date.	Description of sample.	Cane sugar.	Reducing sugar.
			per cent.	per cent.
1	3rd March 1912..	Agamata	63·44	16·05
2	....	Farasumata	66·54	14·72
3	4th March 1912..	Farasumata	49·32	17·66
4	Do. ..	Chitu (final molasses) ..	32·49	20·18
5	Do. ..	Chitu	31·11	17·66
		Final cane Molasses (Country process).[1]	35·92	20·30

An analysis of final molasses from cane sugar is added to the table for comparison. This molasses was obtained by centrifugalising the rab, boiling down the molasses again, and after crystallisation centrifugalising again.

Nos. 1 and 2 were mixed in equal proportions to form the molasses used for the boiling experiment. Nos. 4 and 5 were samples drawn from different lots of sugar.

The amount of raw sugar and molasses obtained by this native refining process is fairly constant from year to year and in all the factories. I am much indebted to Mr. H. C. Macleod for kindly placing the books of various factories at my disposal.

[1] Clarke & Banerji, Efficiency of the Hadi Process, Agri. Jour. of India, Vol. V, Part I, page 35.

Including first and second sugar and molasses and taking the average of three factories for 10 years past we get the following figures :—

Weight of gur.	Weight of 1st and second sugar.	Weight of molasses.	Wastage.
100	41	50·5	8·5

Of the 41 per cent. of raw sugar obtained 29·5 are recovered in the first sugar and the remainder, 11·5, in the second sugar.

To shew how constant is the amount of sugar obtained from the gur the following figures are given shewing the extreme variation in the three factories over the past 10 years. From 100 parts of gur the amount of sugar obtained varied from 37·5 to 43·7 and of molasses from 48 to 55·3.

Each of the three factories above-mentioned refines from 9,000 to 12,000 bazar maunds of gur annually.

The price paid for gur by the refiners varies considerably from year to year. If raw sugar sells at a good price one year, then gur next year goes up in price. With a decrease in the selling price of raw sugar there follows next year a decrease in the price of gur.

Prices of Gur and Molasses.—The following table sets out for 12 years, the price at which gur was bought and sugar and molasses sold by three refineries in Jessore District :—

Season.	Price of gur per md. katcha.[1]			Selling price of sugar per md. katcha.			Molasses sold per maund katcha.		
	Rs.	As.	P.	Rs.	As.	P.	Rs.	As.	P.
1898–99	2	0	9	5	2	6	1	7	1½
1899–00	2	4	6	5	9	7½	1	9	2
1900–01	2	9	0	4	8	3	1	11	0
1901–02	1	14	9	4	3	2	1	5	9
1902–03	1	12	6	4	10	6	1	1	6
1903–04	1	13	6	4	4	0	1	3	10½
1904–05	2	3	7½	5	6	7½	1	9	3
1905–06	2	9	11	4	13	11	2	1	4½
1906–07	2	4	0	4	9	9	1	3	10
1907–08	2	0	0	5	4	0	1	7	0
1908–09	2	3	6	4	11	0	1	4	6
1909–10	2	5	4½	5	3	0	1	8	0

[1] One katcha maund = 40 seers of 60 tolas each; one pucca maund equals 40 seers of 80 tolas each and one pucca or bazar maund equals 82·2 lbs.

Sugar in 1899-1900 sold at the high price of Rs. 5-9-7½ per katcha maund. In 1900-01 the price of gur was very high indeed as a consequence, *viz.*, Rs. 2-9. The same effect was noticed in 1904-05 to 1905-06.

In 1901-02 sugar sold badly at Rs. 4-3-2 and the price of gur in 1902-03 fell in consequence to Re. 1-12-6.

A study of the above table shews what the ratio of the purchase price of gur to the selling price of the sugar must be in order to give a profit.

The cultivators do not sell gur direct to the refiners; a class of middlemen (Vern. *paikars*) exist, who go round and buy gur from the cultivators and then take it in carts to the refiners.

It appears that any rise of price in gur generally goes into the pocket of the middlemen, as the cultivators always get about Re. 1-14-0 from the paikars. This year (1911-12) the cultivators were getting from the middlemen Re. 1-14-0 to Rs. 2-0-0 per katcha maund for their gur, whereas the middlemen were getting Rs. 2-7-0 from the khandsaris.

The middlemen who have gur to sell bring it to the refiners stored in ghurras packed in carts. The purchaser tests its quality by pushing an iron auger into the gur. He can tell the amount of sugar crystals present by the amount of grittiness he feels and he pays for it accordingly. Last year (February 1911), Rs. 2-4-0 per katcha maund was being paid for the best quality. About 90 per cent. of all the gur is of this quality. For the next best quality Re. 1-14-0 was being paid and it represents about 3—4 per cent. of the gur. Of the worst quality there is only 2—5 per cent. and it fetches Re. 1-4-0 to Re. 1-6-0.

The accompanying table gives the analyses of a number of gurs.

Description of gur, native test.	Sucrose.	Reducing sugar.
	%	%
Best quality	72·56	6·92
Do.	79·69	5·01
Do.	77·21	5·51
Do.	75·04	3·30
Intermediate quality	61·40	12·59
Do.	70·35	9·54
Do.	54·57	8·83
Worst quality	60·39	15·32
Do.	61·95	14·80
Do.	53·33	16·85
Do.	58·46	16·59
Unclassed	71·40	12·10
Do.	61·76	12·82
Do.	70·47	7·46
Do.	73·39	11·04
Do.	66·40	10·09
Do.	74·13	7·04
Do.	79·26	10·09
Do.	73·51	9·30
Do.	74·07	9·30
Do.	69·05	3·93
Do.	75·98	2·23
Do.	74·57	4·13
Do.	66·88	2·58
Do.	69·40	5·30
Do.	73·07	6·60
Do.	72·24	9·34
Do.	72·17	7·86
Do.	71·94	5·53
Do.	42·23	26·88
Do.	66·16	9·37
Do.	58·38	11·94
Do.	74·63	5·41
Do.	73·77	7·59
Do.	69·87	10·06
Do.	69·47	15·08
Do.	61·23	13·96
Do.	64·61	12·28

The samples marked unclassed were the gurs examined in the boiling experiments. The other analyses shew that the native method of valuing is very reliable.

Marketing the products.—The following may be of interest in giving information as to where the sugar and molasses are sold. The prices obtained have already been shewn in the tables.

Raw sugar. Formerly this used to find markets in the Narainganj, Mymensingh, Tipperah and Barisal districts. Cossipore used to buy largely, but chiefly the lower qualities for refining. Within

the last three or four years the demand from all these quarters has almost ceased. Cossipore stopped taking it five years ago, since Java sugar has been low in price and they seldom take any now.

The present market is Calcutta where it is brought to meet up-country demands and largely used for sweetmeat making, and it is also refined by a country process at Sukchar near Calcutta. At Sukchar, Dobarrah and Akbarrah sugars are made in fairly large quantities.

Molasses. Until the last 3—4 years there used to be a good market for this around Dacca, Mymensingh and Barisal Districts, where it was used for mixing with tobacco for the native hookah. Some went to Sylhet where it was largely consumed as a food. Some always went to Calcutta for the rum factories. Since the advent of Java molasses the Sylhet market is cut off and the other districts mentioned only take it when the Java crop is short. The rest goes to Calcutta for making rum and country liquor and for mixing with tobacco.

Present Condition of the Native Refining Industry.

Most of the larger towns in the date-sugar-producing districts have their sugar karkhanas (factories), which give to the town a characteristic appearance. In the first place, one is struck by the good quality of the streets within the towns. This is due to the fact that the earthen pots in which the refiners buy the gur, after being smashed to obtain the gur, are thrown in heaps in the street. Dogs, jackals, sheep, goats and cattle may be seen in scores licking the sugar from the pieces. The pieces gradually get broken up and are then spread evenly over the road, and finally get broken down to a powder which makes a splendid road surface.

Next one cannot help remarking the number of old brick walls and chimney stacks. Each karkhana is surrounded by walls, on which are built godowns for the sugar. Kotechandpur at present reflects the declining state of the industry. One can see all round

dilapidated walls and chimneys, the remains of factories no longer working. Year by year more are passing into disuse, and whereas 20 years ago there were perhaps 80 karkhanas working in Kotechandpur alone, there are now only about 30. The year 1911-12 has shewn a tremendous falling-off in the amount of gur worked by the Kotechandpur karkhanas, the amount being only about $\frac{1}{3}$ of that worked last year. This was mainly due to the fact that the karkhanas would not pay the high price, Rs. 2-7-0 per katcha maund, which the middlemen were asking for the gur. When it was seen how fast the price of sugar was rising, the owners of karkhanas began to feel sorry they had not bought more gur at Rs. 2-7-0. Akrah sugar, the product of the karkhanas, was, in February 1912, selling at a higher price than has ever been known before in the history of the date-sugar industry. The gur was consequently being exported to other districts and even to Calcutta, where the price of better classes of sugar being so prohibitive, the date-sugar was in large demand for direct consumption by the people.

The following account sheets shew the scale on which a karkhana works, and also the cost of working it. The figures have been obtained through the courtesy of H. C. MacLeod, Esq., of Kotechandpur and are quite reliable, the writer having been kindly given access to the account books of the factory.

The three years have been selected at random and are quite typical. 1906-07 and 1908-09 were obviously bad years for the karkhanas and 1907-08 a very good year. 1906-07 was a bad year because the prices obtained for the sugar and molasses produced were very low, *viz.*, Rs. 4-8-1$\frac{1}{2}$ and Re. 1-3-10$\frac{1}{2}$ respectively. 1907-08 was a good year due mainly to the low prices at which gur was bought (*viz.*, Re. 1-15-10$\frac{1}{2}$), and to the good prices obtained for sugar and molasses, *viz.*, Rs. 5-4-0 and Re. 1-7-9 respectively. 1908-09 was again a bad year owing to sugar only fetching Rs. 4-12-10$\frac{1}{2}$ and molasses Re. 1-4-7$\frac{1}{2}$ per katcha maund. In the accounts no allowance has been made for interest on capital. This is generally put at 12$\frac{1}{2}$ per cent. in the district.

During the three years 1906-07, 1907-08 and 1908-09 the cost of working one katcha maund of gur in 3 factories has varied from annas four, pies ten to annas five, pies four and a half. This figure is exclusive of interest on capital.

1906-07.

Expenditure.	Rs. A. P.	Income.	Rs. A. P.
House rent	400 0 0	By sale of 3,423 mds. 37 srs. 3 chhataks sugar.	15,439 11 6
Breaking pots	82 12 6		
Servants' food	229 12 4½	By sale of 4,746 mds. 12 srs. molasses.	5,875 7 0
Municipal tax	32 14 0		
Wages to coolies	828 5 3	Balance (loss)	2,179 2 10½
Gunny bags	143 5 6		
Weeds (*Vallisnerice*) See page 359	129 8 0		
Coal	287 12 9		
Empty pots in which molasses are sold.	188 12 0		
Commission to buyers' agents	30 5 9		
Miscellaneous	405 11 6		
Baskets and mats to replace old ones.	191 2 6		
Bad debts	1 7 6		
Purchase of 9,005 mds. 15 seers of gur.	20,542 7 9		
Total ...	23,494 5 4½	Total ...	23,494 5 4½
Average cost of working 1 md. gur.	0 5 3		

1907-08.

Expenditure.	Rs. A. P.	Income.	Rs. A. P.
House rent	465 0 0	By sale of 4,180 mds. 12 srs. 12 chhataks sugar.	21,926 12 3
Breaking pots	89 15 9		
Servants' food	163 11 9	By sale of 4,645 mds. 1 sr. 4 chhataks molasses.	6,892 2 0
Municipal tax	31 6 6		
Wages to coolies	833 8 0		
Gunny bags	132 15 9		
Weeds	138 0 6		
Coal	299 11 6		
Empty pots in which molasses are sold.	232 11 6		
Commission to buyers' agents ...	51 4 3		
Miscellaneous	589 9 3		
Baskets and mats to replace old ones.	9 15 6		
Purchase of 9,568 mds. 11 seers of gur.	19,096 5 6		
Balance profit	6,684 10 6		
Total ...	28,818 14 3	Total ...	28,818 14 3
Average cost of working 1 md. gur.	0 5 1		

1908-09.

Expenditure.	Rs. A. P.	Income.	Rs. A. P.
House rent	475 0 0	By sale of 5,922 mds. 21 srs. sugar.	27,559 0 9
Breaking pots	128 6 6	By sale of 6,758 mds. 28 srs. 8 chhataks molasses.	8,692 5 9
Servants' food	226 0 3		
Municipal tax	51 9 6		
Wages to coolies	1,266 12 9		
Gunny bags	93 2 3		
Weeds	183 8 0		
Coal	485 4 6		
Pots in which molasses is sold	310 6 6		
Commission to buyers' agents	11 14 9		
Miscellaneous	1,006 11 0		
New baskets for draining gur...	33 5 9		
Bad debts	4 8 0		
Purchase of 13,822 mds. 34 seers of gur (katcha).	31,066 11 0		
Balance (profit)	908 1 9		
Total ...	36,251 6 6	Total ...	36,251 6 6
Average cost of working one maund gur.	0 4 11¼		

History of the Native Refining Process.

The pioneers of the process were certain members of the *Mayra* or confectioner's caste who started operations about 1820. The table[1] will give an idea of the rapidity of growth in numbers of these native refineries. We have only been able to find figures for the Jhenidah and Magurah sub-divisions of Jessore.

Year.	Number of factories.	Outturn of sugar maunds katcha.	Outturn of treacle.
1861–62	....	4,465	1,042
1862–63	10	27,215	10,595
1863–64	15	10,633	4,242
1864–65	19	32,675	18,556
1865–66	24	40,009	31,577
1866-67	36	49,713	36,183
1867–68	47	46,671	59,446
1868–69	55	56,898	86,518
1869–70	65	71,251	87,873
1870–71	75	79,032	90,632
1871–72	85	90,222	90,021
1872–73	113	136,992	197,389

[1] Taken from Report on the Agric. Statistics of Jessore, Jhenidah and Magurah sub-divisions, 1872-73. Babu Ramshunkar Sen.

It can be seen from this table how rapid was the growth of this native refining industry. In course of time it practically monopolised the sugar trade and throve till about 1890 when it began to suffer from the competition of imported sugar. This decline has continued, but in 1900-01 there were in Jessore district 117 factories with an outturn valued at Rs. 15,15,000. These small factories are scattered over the district along the banks of the various rivers, but the great centre of manufacture and trade is the town of Kotechandpur on the Kabadak river. In spite of this decline Jessore is still the chief date-sugar-producing district in Bengal, the outturn per annum being estimated at 1,221,000 cwts. out of a total of 1,559,679 cwts. for the whole province.[1]

The Native Date-Sugars.

The native date-sugars on the market with their approximate prices[2] are :—

	Price per md. Rs. As.			Rs. As.	
Dobarrah	11	0	to	11	8
Akbarrah	10	0	,,	10	8
Jodurhatty Dollo	8	8	,,	9	8
Goburdanga Dollo	8	0	,,	9	0
Gnour	6	8	,,	7	0
Akrah	6	0	,,	6	4

The way in which Akrah, Gnour and Dollo sugars are prepared has been described at page 359.

The prices are difficult to understand. Jodurhatty Dollo is quoted at a 50 per cent. higher price than Akrah, whereas both are prepared by an exactly similar process. For information as to the manufacture of Jodurhatty Dollo we are indebted to the Office of the Director of Agriculture, Bengal. We are informed, however, that smaller quantities of gur are refined at Jodurhatty and Goburdanga than at Kotechandpur, and a better quality of sugar is thus obtained at the former places. The appearance of the sugars presents some

[1] N. N. Banerjee: The date sugar palm. Quarterly Journal, Bengal Agricultural Department, January 1908, pp. 161-62.

[2] *Capital*, 27th April 1911.

differences. Goburdanga Dollo and Jodurhatty Dollo are distinctly whiter than Akrah.

However, Gnour has been frequently quoted in *Capital* at a higher price than Akrah. In appearance it is a long way inferior, being a dirty brownish sugar, whereas all the others are greyish white. By its origin also we know that it is an inferior sugar.

The Kotechandpur refiners get a higher price for their Akrah. In April 1911, Kotechandpur Akrah was selling in Calcutta at Rs. 6-10-0 to Rs. 6-12-0 per bazar maund and Kotechandpur Gnour at Rs. 6-2-0 to Rs. 6-6-0. Personal enquiries by the author in the Calcutta sugar market would seem to show that the higher quotation of Gnour than Akrah was a mistake, as the dealers say Akrah always fetches a higher price.

Dobarrah and Akbarrah Sugars.

The process of making these sugars has not varied much from what it was 50—60 years ago when Robinson described it.[1] Dobarrah is the highest state of refinement except candy to which native sugar is brought. It is made only from Dollo, Akrah or Gnour. As a rule, these are sold direct to big markets such as Calcutta, but when they are only fetching a low price, some of the Khandsaries make them into Dobarrah and Akbarrah sugars, which are very highly refined products.

In the process, as we have seen it, two under-ground furnaces are prepared, the fuel in use being coke. On each of these a big iron pan is placed. Each was 3′ 5″ in diameter and 20″ deep. Each pan is now about $\frac{1}{3}$ filled with lime water which had been made by adding 1 seer of lime to about 6 maunds of water and after continued stirring allowed to stand overnight. All earthen pans in which Dobarrah and Akbarrah sugars had been prepared and which were now empty are well rinsed in the iron pans to get out any sugar. About $4\frac{1}{2}$ maunds of (370lbs.) Akrah sugar are now placed in each

[1] Bengal Sugar Planter, Robinson, p. 83.

pan and well mixed up with the lime water. More water is now added equal in bulk to that of the lime water originally present. The contents of the pans are now heated with continued stirring and any pieces of foreign matter such as pieces of *ghurras* taken out by means of a perforated ladle. Two brass pans 20″ in diameter and $8\frac{1}{2}$″ deep are now carefully cleaned and one put by the side of each of the big melting pans. Two seers (4lbs.) of milk are placed in each and then they are filled with water. When the liquid comes to the boil this diluted milk is gradually sprinkled over the surface of the boiling liquid until it is all used up. Scum is removed after each sprinkling with milk by means of flat perforated iron ladles. Rather a liberal amount of scum is taken off but it is all carefully preserved in a spare pot. After 3 or 4 hours all the sugar has dissolved and all the scum has been removed. The fire is then damped and one bucketful of cold water added to each of the melting pans. A third large iron pan equal in size to each of the melting pans is now put ready with a cloth strainer over it. The hot liquid is strained through this into the third pan and it is now ready for a final clarification and concentration. The scum removed from the melting pans is now put back into one of them again and reboiled and reclarified with milk. There is so much scum that it fills one-third of one of the pans. Pieces of grass and dirt are taken out of the scum with a ladle, being carefully washed with diluted milk on the ladle and well pressed before being thrown into the fire. After 10 to 15 minutes the liquid is removed from the fire and strained through gunny cloth. The strained liquid is put on the melting pots at the next melting of Akrah. The scum, which is a black mass, is re-boiled with lime water and after further straining thrown away. The iron melting pans having been removed from the fires, the brass pots above mentioned are put on in their stead. Each is three-fourths filled with hot strained juice which is now brought to the boil. One spoonful of milk is added to the boiling liquid from time to time and any scum is skimmed off, but it only forms in small quantities. The liquid is of a lovely golden yellow colour and is boiled until it shews signs of stickiness on

being dropped from the end of a stick. In all, three to four spoonfuls of milk are added.

The concentrated clarified liquor is now poured into a shallow earthenware pan 21″ in diameter and $8\frac{1}{2}$″ deep and put by in a store-room. The brass pans are again filled and the process repeated until all the contents of the storage pan have been worked off.

A number of flat earthenware pans are thus obtained, each containing concentrated liquor. In about 6 hours crystallisation begins to take place. The liquor is never seeded with sugar crystals in order to make it crystallise as is done in some of these native processes.

By next day the contents of each pan have set to a solid mass with a yellow brown glassy surface. If the surface is sunken in the middle, the refiners say the boiling has been bad and the sugar will not be of the best quality.

Two days later the glassy surface is scraped to loosen it and then a layer of about 3″ thick of water weed (*Vallisneria spiralis*), locally called *pata shyala*, is put over the surface. This weed remains moist for a long time. A hole is now driven through the bottom of the pan by means of an iron punch and hammer and the hole made right up through the sugar.

The pan is next placed on a triangular frame work, over an earthenware pot. Molasses drains away from the sugar. It might be mentioned here that these pans are later repaired by simply sticking thick paper over the hole and are thus able to be used over and over again.

After 4 days the *shyala* weed is removed and the top half of the contents of the pan is a pure white rather large-grained sugar and is broken up and spread in the sun to dry on bamboo mats. This is Dobarrah sugar.

The nether portion of the sugar is still mixed with some molasses and is brown. The nether portions of two or more pans are mixed until sufficient is obtained to make up another pan, and then *shyala*

weed is again applied to the surface. After another 4 days a fresh crop of Dobarrah sugar is obtained from the surface. The nether portions, which are still brown, are mixed with the two lots of molasses obtained above and reboiled. The clarifying, boiling, and weeding are carried out in an exactly similar way as when first boiling the Akrah alone. The resulting sugar is Akbarrah. It is of rather smaller grain than Dobarrah and of slightly reddish tinge. The syrup from Akbarrah is sold as molasses and at times attempts are made to reboil this syrup into a third grade of sugar called *petiar chini*, but in the case we saw the attempt was not successful. We made an analysis of the liquor and found—

Sucrose	55·6
Reducing sugar	33·96

It was not surprising that no crystals could be obtained in this case. The nether portions of sugar of the Akbarrah draining pans are still brown and are mixed with the next lot of Akbarrah boilings.

The following analyses shew the composition of samples taken at Kotechandpur of Dobarrah and Akbarrah sugars and of the Akrah sugar from which these were made.

	Sucrose.	Reducing sugar.
Dobarrah	98·32	0·78
Akbarrah	97·18	1·47
Akrah	94·43	2·33

The author has met with Dobarrah sugar, containing 99·4 per cent. sucrose and only a trace of invert sugar. The Akrah analysed above was richer in sucrose than this sugar usually is.

Consumption.—They are mainly consumed by the richer classes of natives such as the Marwaris, who give a high price because the sugars are prepared in accordance with their caste prejudices.

Samples of all the above native date-sugars, as quoted in *Capital*, were kindly obtained for us from the Calcutta market by the Office of the Director of Agriculture, Bengal.

Analyses have been made to see if the sugar contents justified the large differences in price between the sugars.

	Dobarrah.	Akbarrah.	Jodurhutty Dollo.	Goburdanga Dollo.	Gnour.	Akrah.
Sucrose ..	98·48	98·37	96·50	95·17	91·74	92·75
Reducing Sugar	0·81	1·14	1·62	1·91	2·86	2·19
Water ..	0·22	0·30	0·82	0·91	1·40	0·94
Total ash ..	0·05	0·09	0·23	0·41	1·11	1·22
Organic matter not sugar ..	0·44	0·10	0·83	1·60	2·89	2·90
	100·00	100·00	100·00	100·00	100·00	100·00
Insoluble matter	0·01	0·14	0·45	1·35	1·68	1·31
Soluble ash ..	0·00	0·00	0·10	0·20	0·10	0·02

To show that the native does not pay for his sugar on the sucrose content but that the prices depend on mere fancy the following analyses and prices are quoted. These prices are taken from *Capital* of the same date from which those of date-sugars on page 369 were taken.

Description of sugar.	Price per bazar maund.	Sucrose. %	Reducing sugar. %
Java T. M. O. white	7 3 0	99·60	0·25
,, brown	6 4 0	97·54	not determined
Cossipore first white	8 8 0	99·90	trace
Dobarrah	11 4 0	98·48	0·81
Akbarrah	10 4 0	98·37	1·14
Jodurhatty Dollo	9 0 0	96·50	1·62
Goburdanga Dollo	8 8 0	95·17	1·91
Gnour	6 12 0	91·74	2·86
Akrah	6 2 0	92·75	2·19

For convenience of reference the date-sugars are inserted on the table and the average quotation price is put beside them.

From the analyses it is seen that Akrah is distinctly a better sugar than Gnour. Since also we know by its process of manufacture that it is a better sugar, it is, as before stated, probable that a mistake has been made by *Capital* in the quotation of Akrah and Gnour.

The Dollo sugars are certainly much better than Akrah, but it seems hard to find a reason for the fact that Jodurhutty Dollo is quoted at a 50 per cent. higher price than Akrah.

Java T. M. O. white is a better sugar than Dobarrah though it fetches only 60 per cent. of the price the latter does. In this case one must put down the difference in price to the great prejudice in favour of native sugars.

The following are the only other analyses of date sugar which I have been able to find.

The first is described as an analysis of date sugar as sold in Calcutta and is by M. Deon.[1]

	%
Sucrose	87·97
Reducing sugar	1·71
Gum	4·88
Water and volatile matter	1·88
Ash	0·50
Mannite, fatty matter, matters not estimated and lost	3·06
	100·00

M. Deon states that the sugar was in full viscous fermentation and that it is known that this fermentation is accompanied by the formation of mannite and a gummy substance. This gum is soluble in water, insoluble in alcohol, precipitated by sub-acetate of lead, dextrorotatory, without action on Fehling solution and converted into glucose on boiling with dilute acids.

Thorpe's Dictionary of applied chemistry[2] quotes an analysis made in England of palmyra jaggery.

	%
Sugar	78·00
Glucose	8·93
Ash Soluble	1·71
,, unsoluble	0·86
Moisture	6·74
Undetermined organic matters	3·76
	100·00

[1] Bull. Soc. Chim. de France.

[2] Vol. III, p. 624.

Deterioration of Date Sugars on Storage.

Some date sugars which were analysed in June 1911, were stored away in glass stoppered bottles. On opening the bottles in April 1912 all the samples had a more or less offensive smell and all the sugars were again analysed. It was found that a good deal of change had gone on in their composition. The results are set out in the accompanying tables.

	June 1911.			April 1912.		
	Sucrose.	Reducing sugar.	Total sugar.	Sucrose.	Reducing sugar.	Total sugar.
Dobarrah	98·48	0·81	99·29	97·07	2·64	99·71
Akbarrah	98·37	1·14	99·51	96·62	2·79	99·41
Akrah	92·75	2·19	94·94	88·32	4·56	92·88
Gnour	91·74	2·86	94·60	87·25	5·95	93·20
Jodurhatty Dollo ..	96·50	1·62	98·12	91·52	5·18	96·70
Goburdanga Dollo ..	95·17	1·91	97·08	92·64	3·88	96·52

A fresh set of samples of date sugar made in 1911-12 season were analysed and put up in glass stoppered bottles on May 5th, 1912. They were again analysed on 18th June 1912. The results are here set out.

	5th May 1912.			18th June 1912.		
	Sucrose.	Reducing sugar.	Total sugar.	Sucrose.	Reducing sugar.	Total sugar.
Dobarrah	98·81	0·88	99·69	98·58	1·11	99·69
Akrah	94·43	2·33	96·76	93·95	2·94	96·89
Chulta	94·56	3·99	98·55	93·40	2·55	95·95
Gnour	95·48	2·61	98·09	92·19	5·04	97·23

The table shews that even in such a short period as 6 weeks these native prepared sugars have deteriorated to a large extent. Greig Smith[1] and Owen[2] have observed this deterioration of raw sugars on storage. We have not examined the nature of the change, but it is probably bacterial as was shewn by Greig Smith in the case of Australian raw sugar.

[1] Greig Smith. Proc. Royal Society, N. S. W.

[2] W. L. Owen. Bacterial Decomposition of Sugars, Louisiana Planter, 1911, 46, 153-5.

PART IX.

Commercial.

Past and Present prices of Gur, Akrah and Molasses.

In the following table have been collected together the prices of the above products for as many years as I have been able to find them.[1]

Year.	Price per Katcha Maund.		
	Gur.	Akrah.	Molasses.
	Rs. A. P.	Rs. A. P.	Rs. A. P.
1832	1 2 0	3 10 3	
1833	1 2 6	3 10 0	
1834	1 5 4	4 2 4	
1835	1 11 8	4 7 6	
1836	1 7 0	4 4 9	
1837	1 10 6	4 6 9	
1838	1 10 0	4 6 3	Average 0 12 0
1839	1 12 0	5 10 6	
1839—40	1 14 11	6 5 5	Varied from 0 8 0
1840—41	3 1 9	8 6 10	to 2 0 0
1842	1 12 0	4 14 3	
1843	1 15 0	6 12 5	
1844	2 0 0	6 12 5	
1845	1 13 0	6 10 9	
1846	1 14 0	7 13 0	
1847	1 14 0	5 14 6	
1852	0 12 0		
1861—62	......	4 0 0	1 0 0
1862—63	......	7 15 0	0 6 6
1863—64	......	9 3 0	1 1 0
1864—65	......	3 12 0	1 15 0
1865—66	......	4 1 6	1 1 6
1866—67	......	4 15 0	1 6 0
1867—68	......	12 10 0	1 2 6
1868—69	......	5 5 6	1 2 6
1869—70	......	6 6 0	1 3 6
1870—71	......	6 1 3	1 2 0
1871—72	......	6 5 0	1 2 0
1872—73	......	5 15 0	2 0 6
1873	1 13 0	7 0 0 to 10 8 0	

[1] Bengal Sugar Planter. S. H. Robinson, 1849 Report on the Agric. Statistics of Jessore, 1872-3, B. Ramshunkar Sen.

Year.	Price per Katcha Maund.		
	Gur.	Akrah.	Molasses.
	Rs. A. P.	Rs. A. P.	Rs. A. P.
1898—99	2 0 9	5 2 6	1 7 1½
1899—1900	2 4 6	5 9 7½	1 9 2
1900—01	2 9 0	4 8 2	1 11 0
1901—02	1 14 9	4 3 2	1 5 9
1902—03	1 12 6	4 10 6	1 1 6
1903—04	1 13 6	4 4 0	1 3 10½
1904—05	2 3 7½	5 6 7½	1 9 3
1905—06	2 9 11	4 13 11	2 1 4½
1906—07	2 4 0	4 9 9	1 3 10
1907—08	2 0 0	5 4 0	1 7 0
1908—09	2 3 6	4 11 0	1 4 6
1909—10	2 5 4½	5 3 0	1 8 0

Certainly since 1898 there does not seem to be any tendency towards a marked increase of price of either date sugar, molasses or native refined sugar.

In the case of cane gur on the other hand during this same period there has been an increase in price of something like 25 per cent.[1] Date gur in ordinary years does not fetch more than Rs. 2-4 per katcha maund. This is equivalent to Rs. 3 per pucca maund and is considerably less than the price of cane gur.

Profits of the Industry.

It is a matter of extreme difficulty to set forth satisfactory estimates showing the profits to be derived from the industry. The writer however has carefully studied a number of estimates which have been previously published. By the help of these and of personal enquiries among the cultivators he has arrived at the following figures. In the calculations he has taken 350 trees as the basis, the number which could be grown on one acre. For this they would have to be planted rather less than 12 feet apart. Two gachis (tappers) with an assistant (kheri) would be easily able to manage all the trees.

[1] Notes on Sugar in India, F. Noel Paton, p. 23, and also Rural Economy in the Bombay Deccan. G. Keatinge, p. 184.

Outlay.

	Rs.	A.	P.
2 Gachis for season	48	0	0
Kheri	15	0	0
Food for above	38	4	0
Fuel	30	0	0
Pots and pans	15	0	0
Daws	1	0	0
Rope	1	0	0
Rent	15	0	0
Ploughing and weeding	9	0	0
Jute	0	12	0
Clothes for kheri and gachis	2	0	0
Rent[1] to zemindar for keeping up a bain ..	2	0	0
TOTAL ..	177	0	0

Income.

350 trees at 22½lbs. gur per tree produce 98·4 maunds (pucca), which, at 2-8-0 per maund, are worth Rs. 246-4-0.

Profit 69-4-0

It must be remembered that the first gur of the season, the *nolen-gur* fetches a much higher price than Rs. 2-8-0 per pucca maund which is the price taken above. So that the above income is much understated on this account.

The profit works out therefore at about 3½ annas per tree per year and would make out the industry, even in its present state to be a quite remunerative one. Further, if the owner of the trees helped to work them himself he would save a good deal in wages.

The above calculations have not taken into consideration the fact that it takes 5 or 6 years from the time of planting before a garden comes into bearing. During that time the following expenses are incurred.

6 *Years' cost of getting Plantation ready for use.*

	Rs.	A.	P.
Cost of sowing seed	3	0	0
6 years' ploughing and weeding	50	0	0
6 years' rent	90	0	0
TOTAL ..	143	0	0

1 The amount of this is based on the number of openings in the furnace such as spaces for pans, stoke holes, and smoke escape holes.

Since the garden will go on bearing for fully 25 years this amount is not very serious as in the long run it would add less than Rs. 6 per annum to the expenditure. Further, during these 6 years a certain amount of income can be obtained by growing crops on the land. The author has already stated reasons why he thinks the estimate of income is low and even allowing for the sum of Rs. 6 per annum he still thinks it is not too high.

At the same time it is obvious that a man who wishes to set out a date garden must have a fair amount of available capital.

Here it might be mentioned that trees are usually let for sugar manufacture at 8—16 to the rupee and the people themselves reckon on a profit of anything from 4 to 12 annas per tree.

The profit of Rs. 69-4-0 per acre does not represent the whole of the profit obtained from the garden for under the date trees a cold weather or *dhan* crop can be raised. If arhar is grown the stalks are extremely useful as fuel and this will tend to reduce the high figure allowed for fuel in the above estimate. The wood of the date trees is used as beams and posts in houses and as ladders in tanks and ghats. It is also used in constructing temporary bridges over streams and drains. The leaves cut off before tapping are used as fuel and last one month for this purpose. At Kaliganj bags are made from the leaves for exporting sugar.

PART X.

Suggestions for Improvements.

In the preceding pages we have shewn how important an industry the manufacture of date sugar is. The amount produced in Bengal alone is probably about 100,000 tons worth well over £500,000 sterling. This industry is a source of profit to a large number of people.

The methods of sugar manufacture and refining carried out in the district are very crude and in the author's opinion are capable and worthy of great improvement.

It has been shewn that even in the present state of the industry, by the regular planting of 350 trees per acre, one can expect as an average nearly 3 tons of gur per acre. This is a much higher yield than could be obtained in the district from sugarcane. Further, there is a good deal of risk in the growth of cane which may be damaged by floods, pests, etc., and also much labour and expense is involved in its growth. With date palm the yield of sugar is certain from year to year and very little expense has to be incurred for actual cultivation.

In these recommendations we are mainly considering the improvements from the point of view of a native industry.

At the same time there seems no reason, why with careful seed selection the amount of sugar in the juice should not be raised considerably and under these circumstances there *might* be openings for large central factories, especially as there would be no need of crushing apparatus, which is such an expensive part of a factory dealing with cane. As a set off against this, however, we must remember that the megasse or cane from which the juice has been extracted, serves as fuel in the cane sugar factory. In order to boil

the date juice fuel would have to be purchased. The writer here calls attention to the long season which is possible with palm sugars. Thus the date palm yields its juice in the cold weather, from November to March. The Palmyra Palm (*Borassus flabelliformis*) yields its juice in the hot weather from April to September. There are many places where these palms would grow very well side by side and thus a factory would be able to make its sugar boiling season last over practically the whole year.

In considering this subject of improvements it will be instructive to refer to the maple-sugar industry of North America. The early settlers in that country learned the art of making maple sugar from the Indians, who simply made axe-cuts in the trees and inserted a rough wooden spout, very similar to the bamboo spout now used in Jessore. The juice was collected in rough wooden troughs and boiled down in clay or bark vessels by dropping hot stones into the sap. The white settlers carried on the same process for one hundred years without material change, save for the substitution of iron or copper kettles for the clay or bark vessels. They also boiled the juice down over a fire of timber instead of dropping hot stones into it. The crude product of those early days was quite dark in colour and very unreliable in quality.

About the middle of last century a rapid improvement in the methods and machinery employed, took place.[1] Instead of the old destructive axe-cut, holes are carefully drilled into the trees with an auger or bit and closed metal spouts have been substituted for the old wooden spouts. Similarly, tin or galvanised iron pails fitted with covers have gradually taken the place of the rough wooden troughs which formerly caught the sap. At first the sap was generally carried to the fire in buckets by hand or with a shoulder yoke. But as the scale of operations increased, gathering tanks were introduced and are now used in all but the smallest groves. These are placed at convenient distances throughout the grove. From these pipes are often run through the grove to larger storage tanks

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[1] See U. S. Dept. of Agri. Farmers' Bull., No. 252.

or the sugar house. In one large grove a narrow-gauge railway is used for collecting sap. The change in the actual process of making sugar is described as revolutionary. This is chiefly due to the supplanting of the iron kettles for boiling the sap by ingenious and cheap modern evaporators. These are long shallow tanks having partitions from side to side and open at alternate ends placed in them at intervals of 8 to 10 inches. The sap, whose flow is carefully regulated from a storage tank, enters the evaporator at one end and flows slowly across the pan from side to side, around the partitions until it reaches the far end. By this time it is reduced to the required density.

Improvements in methods of firing have been so great that consumption of fuel is much more economical than in the early days. It is understood that in some districts small vacuum pan plants are in use.

There is one great advantage which the date palm sap has over that of the maple. The former contains 10 to 14% of sugar, whereas the latter only contains about 3%. The average annual yield of sugar per tree is in the case of the date palm about $22\frac{1}{2}$lbs., whereas the maple only yields about 3lbs. Further, one acre of land will accommodate many more date palms than maple trees.

At the same time maple sugar and syrup are luxuries and fetch much higher prices than date sugar. The maple sugar sells at 9 cents (equal to $4\frac{1}{2}$ annas) per pound, whereas date gur only brings in to the cultivator half an anna per pound.

We will consider proposed improvements in the date sugar industry under various heads.

I. Agriculture.

Cultivation.—Gardens, especially when young, should be well cultivated. They should be kept ploughed up in the hot weather as this will prevent to some extent loss of soil moisture.

Planting.—A regular system of planting should be followed so as to get the optimum number of trees per acre. The author

considers that trees may be safely put at distances of 11 feet apart each way, that is, 360 trees per acre.

Manuring.—At present the date gardens receive no manure, but it might be found that manuring would be beneficial.

II. Seed Selection.

It seems probable that much might be done by sowing seed taken from the trees which yield large quantities of rich juice. Since the thickest trees have been observed by us to be largest yielders, this selection should be a simple matter.

Near Jessore town at village Khartalar a number of gardens have been sown from seed taken from the excellent garden referred to on page 325. These gardens are full of high yielding trees. It might also be found that the largest seeds would give the biggest plants. It seems to us worth while experimenting in this matter of seed selection.

III. Manufacture of Gur.

In the manufacture of gur there is room for much improvement. The whole process is an extremely dirty one. The earthen pans are never cleaned from one end of the season to the other. The consequence is that burnt sugar and much dirt and many ferments collect in the pans. A good proportion of the dark colour of date gur must be due to the burnt sugar collecting in the pans. Mr. B. C. Basu carried out some experiments on the use of iron pans in Jessore in 1892-4 and states[1] that he prepared jaggery of exceedingly fine quality which was capable of producing almost pure white sugar when treated by the centrifugal. We here append analyses of a sample of gur and of rab prepared in iron pans by Mr. Chatterjee in Central India. These samples were much lighter in colour than the gur prepared in Jessore in earthen pans and it will be seen they are of good quality.

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[1] Reports of Department of Land Records and Agric., Bengal, 1892-3, pp. 32-33 & 1893-4, pp. 16-17.

	Sucrose.	Reducing sugar.
Gur	81·24	2·37
Rab	69·70	3·72

Owing to the fact that the juice is practically neutral in reaction very little loss of sucrose should occur during the boiling process. It certainly seems to the writer that something ought to be done to import iron pans into the district. The real difficulty in introducing them lies in the fact that often such small quantities of juice are boiled by one man that it would not pay him to purchase an iron pan. Something however might be done in the nature of co-operation among the people so that several men could combine their work and purchase a pan between them. It is probable that the larger scale on which the operations could be then carried out would result in a saving of fuel.

IV. Methods of Refining.

The present native method of refining by means of water weed is an exceedingly slow process, but it has the advantage that very little outlay is required. If, however, centrifugals could be introduced the process would be a much quicker one and the turnover would be much greater. The quality of sugar produced would also be much better. Mr. B. C. Basu[1] carried out experiments in Jessore in 1893-4 with the centrifugal and obtained good results when he used good quality jaggery. His remarks shew that his experiments aroused great interest. He concluded that if centrifugals come into use, the cultivators would soon produce a better quality jaggery.

It would further be a good plan if the people could be induced to strain their juice through cloth before boiling it down. Numberless pieces of wood, bark and other impurities are to be found in the juice and on boiling these all tend to darken the syrup.

In the meantime the people should be persuaded to clean out daily the earthen boiling pans which are at present in use. They could be scrubbed clean with water as is done daily in those parts of Jessore district where an eating gur is made from sugarcane.

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[1] Loc. cit.

The cultivator says he does not clean his pans because after putting water in them they are liable to crack on the fire. Yet in the case of boiling the sugarcane juice, when earthen pans are used and cleaned daily with water, the pans seldom crack.

V. Method of Tapping.

The main drawback to the use of date juice for sugar manufacture is its high glucose ratio. The writer has shewn however that the juice as it exudes from a freshly cut surface of the tree contains only sucrose and that the reducing sugars are formed subsequently as a result of fermentation. If this subsequent fermentation could be stopped, the industry should have a great future. It occurred to us that if the trees were tapped by drilling holes into them with an auger then a much higher quality of juice would be obtained for there would not be such a large cut surface exposed to the air. It was found however that the flow of juice from holes drilled into the tree was practically negligible. Indeed, in the native process of tapping it will be remembered that the sap yielding surface is not cut into at once in the beginning of the season. If this is done very small yields of juice only are obtained. The bark is first removed and the delicate underlying tissues are exposed for some time. The copious flow of juice is apparently due to excitation of the tissues due to the wound.

It seemed to us desirable to test the effect of a simple antiseptic in preserving the quality of the juice. Formalin was chosen for this as it is a good disinfectant, easily obtainable and cheap. The experiments on page 342 have shewn how effective the substance is, in preserving date juice. In the field it is impossible to plan experiments to shew exactly how great is its effect. The real difficulty is to find two sets of trees which are yielding exactly similar juice, so that one set may be treated with formalin and one remain untreated. Attempts were made to select groups of trees which would give juice of about the same composition. On several occasions 20 trees were selected and their yields measured. Attempts were made to collect these 20 trees into groups so that two groups might be obtain-

ed in which the composition of the juice was approximately the same. After several experiments it was decided that the variations in the quality of the juice between any two groups which might be so obtained was so large as to make it difficult to obtain a numerical value of the effect of formalin.

This effect was very obvious however. Most of the experiments were done by lightly washing the cut surface in the afternoon with a piece of cotton wool dipped in 10% formalin solution (commercial formalin diluted 4 times). The washing was done by the *gachi* himself in our presence. In almost every case the juice obtained from the formalined surface was quite clear and always much clearer than from untreated trees. Moreover in the morning the untreated surfaces always have a certain amount of yeast growth, whereas the surfaces treated with formalin were practically free from yeast. In order to make certain that the effect was due to the formalin and not to simply the cleaning of the surface, experiments were made in which the surface was washed in a similar way with water. This also lessened the yeast growth but not to such an extent as the formalin did, neither was the juice of such good quality. Perhaps the best proof of the efficacy of formalin was the testimony of the *gachi* himself. He was so pleased with its effect that he wished us to let him treat the whole of his garden in a similar way.

It has been shewn (page 340) that much of the inversion of the sucrose takes place after the juice has left the tree and while it is standing in the pot overnight. Hence it is reasonable to suppose that it would be worth while putting formalin in each pot overnight. In the cases where we tried this, very good juices were obtained. In one case in which one c.c. of 40% formalin was placed in the pot overnight and dokat juice collected, a juice was obtained containing in 100 c.c. 13 gms. of sucrose and 0·35 gm. of reducing sugar. This is a very good dokat juice indeed.

It would be worth while carrying out a more extended series of experiments on the effect of formalin. We should feel inclined to recommend washing the cut surface with formalin once a week

and the addition of a small quantity of formalin to the pots daily. Of course one would have to calculate whether the cost of the formalin so used would be repaid by the extra amount of sugar recovered. About 3 c.c.[1] of 10% formalin[2] would be sufficient to wash each cut surface and one c.c. of 10% formalin[2] might be tried in each pot. Taking 100 trees the amount of formalin per season would then work out as follows :—

3 c.c. per week per tree for 13 weeks equals		3,900 c.c.
1 c.c. per pot for every juice-yielding night, say 44, equals ..		4,400 c.c.
	TOTAL	8,300 c.c. 10% formalin.
	equals ..	2,100 c.c. roughly 40% formalin.
	equals ..	4·6lbs. formalin roughly

4·6lbs. at 12 As. per lb. (market price in bulk in India) is equal to 55 annas per 100 trees or about half an anna per tree. Half an anna per tree is but a very small expenditure.

A 5% increase in yield of sugar per tree would account for it for taking the average yield of gur per tree as 22½lbs. A 5% increase would be about 1lb. of gur.

Any increase in yield over 5% resulting from the treatment would therefore be profit and from our preliminary experiments it seemed that by formalin treatment a very appreciable increase in yield of sugar per tree might be obtained.

VI. System of Collection of Juice.

It has been shewn that much of the sugar is lost by inversion during the night after the juice has flowed from the tree. The dirty state of the earthenware collecting pots must have a good deal to do with the large amount of inversion. Earthenware pots in any case would be difficult to clean, and as a matter of fact the pots are never cleaned from one end of the season to the other, the only treatment they receive being that of smoking. It seems to us that it would be much better if cheap metal pails could be substituted for

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[1] 28 c.c. equals roughly 1 oz.

[2] Dr. Butler, Imperial Mycologist, thinks that probably 1% formalin would be equally effective. If so, then the cost of treating the trees would be very small indeed.

the earthen pots. It would be preferable for the pails to have loosely fitting lids. Such pails could easily be cleaned. We had occasion in some of our experiments to collect juice in an enamelled vessel. The juice so obtained was always of much better quality than that collected in earthenware pots and this can only be ascribed to the more cleanly nature of the enamelled pot.

VII. Carriage of Gur to Refineries.

All the gur is taken to the refineries in the native earthen pots. It has been explained on page 359 that in order to get the gur out of the pots the refiners have to break them. The result is that the sugar always contains a certain amount of small pieces of earthenware. Where European refineries purchase the gur this is a distinct drawback as the pieces of earthenware cut the filter bags which are used in the refinery and thus are a source of great trouble. Again the earthen pots filled with gur when loaded on to a cart are easily broken and it is a common occurrence for a cart thus loaded to upset down a bund, with consequent large loss of sugar. If barrels or metal drums could be introduced in place of these earthen pots these disadvantages would be done away with.

VIII. We have finally to throw out a suggestion which seems to us worthy of experiment. Careful enquiries in the district, conducted chiefly by Mr. H. D. Chatterjee, seem to make it clear that the tappers would sell their juice at 4 to $4\frac{1}{2}$ annas per maund, rather than take the trouble to boil it into gur. It seems possible that an enterprising man might find it worth his while to set up in any given centre and buy juice from the surrounding tappers. He might fit up say a Hadi process plant capable of dealing with 60 to 100 maunds of juice per day and prepare gur. This gur should be of much better quality than the ordinary gur of the district and should fetch a much higher price. In addition a centrifugal might be fitted up for the purpose of producing white sugar.

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